Protecting Manufactured Homes from Floods and Other Hazards

A Multi-Hazard Foundation and Installation Guide

FEMA P-85, Second Edition / November 2009

FEMA

Protecting Manufactured Homes from Floods and Other Hazards

A Multi-Hazard Foundation and Installation Guide

FEMA P-85, Second Edition / November 2009

FEMA

Preface

The Federal Emergency Management Agency (FEMA) first published *Manufactured Home Installation in Flood Hazard Areas* (FEMA 85) in 1985. Since then, manufactured homes have become better built, and natural hazards like flood, wind, and earthquake (seismic) events are better understood.

To benefit from the advances made in the last 24 years, FEMA 85 has been updated to reflect the requirements of the most current codes and standards and to provide a *best practices* approach in reducing damages from natural hazards. While the original version of FEMA 85 concentrated on flood and wind events, this version also addresses seismic hazards and recommends several multi-hazard resistant foundation designs. Designs are included for wood-framed foundations, conventional concrete and masonry pier foundations, and ground anchors. The ground anchor foundations are based on results from a series of first-of-its-kind saturated and dry soil anchor tests. The anchor tests were conducted with the support of the U.S. Department of Housing and Urban Development (HUD), the Manufactured Housing Institute (MHI), the Systems Building Research Alliance (SBRA, formerly the Manufactured Housing Research Alliance [MHRA]), and several ground anchor manufacturers. A detailed example showing step-by-step procedures on how to design a foundation for a manufactured home is also included.

This guidance is also valuable to designers of alternate foundations allowed by the HUD 24 CFR 3285 *Model Manufactured Home Installation Standards*, especially for homes located in Special Flood Hazard Areas (SFHAs) for which certain 24 CFR 3285 foundation designs are not applicable (24 CFR 3285.303, Table 1, Note 4, et al.).

The foundation designs discussed in Chapter 10 and shown in Appendix H of this guide are but one group of acceptable foundation solutions. They should not be considered mandatory or all inclusive. Alternative foundation systems, designed to resist equivalent loads and provide equivalent performance, should be considered equally acceptable.

Limitations of the Guide

This manual has been prepared to assist in protecting manufactured homes from floods and other hazards. Builders, installers, architects, and engineers using this guide assume responsibility for the resulting designs and the performance during a natural hazard event.

The foundation designs and analyses presented in the guide are based on load combinations contained in the American Society of Civil Engineers (ASCE 7-05) and the 2006 version of the International Residential Code® (IRC®).

Acknowledgments

The Federal Emergency Management Agency would like to acknowledge the significant contributions made by the following individuals in developing the Second Edition of this publication.

John Ingargiola
FEMA Building Science Branch

Edward Laatsch
FEMA Building Science Branch

Marcus Barnes
FEMA Building Science Branch

Lois Forster
FEMA Floodplain Management Branch

Brad Loar
FEMA Region IV

Mike Mahoney
FEMA Building Science Branch

Cliff Oliver
FEMA Acquisition Branch

John Plisich
FEMA Region IV

Mike Robinson
FEMA Floodplain Management Branch

Paul Rooney
FEMA Data and Dissemination Management Section

Juanita Thompson
FEMA Floodplain Management Branch

Phil Bergeldt
Florida Department of Highway Safety and Motor Vehicles, Mobile Home and Recreational Vehicle Construction

Mike Blanford
HUD Office of Policy Development and Research

Jason McJury
HUD Office of Manufactured Housing Programs

Rick Mendlen
HUD Office of Manufactured Housing Programs

Kelly Cobeen
Cobeen & Associates

Bill Coulbourne
Applied Technology Council

Deb Daly
Greenhorne & O'Mara

Bill Farish
Clayton Homes

Jeff Inks
Manufactured Housing Institute

Joseph Klein
Dewberry

Emmanuel Levy
Systems Building Research Alliance (formerly Manufactured Housing Research Alliance)

Julie Liptak
Greenhorne & O'Mara

Thayer Long
Manufactured Housing Institute

Dave Low
DK Low and Associates

Bonnie Manley
American Iron and Steel Institute

Therese McAllister
National Institute of Standards and Technology

Ken Morris
Oklahoma Water Resources Board

Mark Nunn
Manufactured Housing Institute

George Porter
Manufactured Housing Resources

Jim Rossberg
American Society of Civil Engineers

Chuck Sanders
former Alabama State NFIP Coordinator

Adrienne Sheldon
URS

John Squerciati
Dewberry

Bill Turney
Florida Manufactured Housing Association

Frank Walter
Manufactured Housing Institute

Mark Weiss
Manufactured Housing Association for Regulatory Reform

Jimmy Yeung
Greenhorne & O'Mara

Naomi Chang Zajic
Greenhorne & O'Mara

Brian Zelenko
URS

Table of Contents

Preface i

Acknowledgments iii

1 Introduction 1-1

1.1 Purpose and Scope of the Guide 1-1

1.2 Background 1-3

1.2.1 Manufactured Homes in the United States 1-3

1.2.2 National Flood Insurance Program 1-5

1.2.3 Performance of Manufactured Homes in Wind and Flood Events 1-6

1.2.3.1 Performance of Pre-1994 Manufactured Homes 1-6

1.2.3.2 Performance of Post-1994 Manufactured Homes 1-7

1.2.3.3 Performance of Manufactured Homes During Hurricane Charley (2004) in Florida 1-8

2 Manufactured Homes 2-1

2.1 Manufactured Home Characteristics 2-1

2.1.1 Chassis Support System 2-1

2.1.2 Integrated Support System 2-2

2.1.3 Envelope Construction 2-2

2.1.4 Double Section 2-3

2.2 Types of Foundation Systems 2-3

2.2.1 Typical Foundation Systems 2-5

2.2.1.1 Typical Installation 2-5

2.2.1.2 Piers and Ground Anchors 2-6

2.2.1.3 Perimeter Wall Foundations 2-7

2.2.2 Proprietary Systems 2-7

2.3 Utilities and Mechanical Equipment 2-8

2.3.1 Utilities Placement 2-8

2.3.2 Mechanical Access....2-9

2.4 Attachments – Carports, Decks, Porches, and Awnings....2-10

3 Regulatory Requirements....3-1

3.1 Introduction to the NFIP....3-1

3.2 Identifying and Mapping Flood Hazards....3-2

3.3 The NFIP's Community Rating System (CRS)....3-8

3.4 NFIP Definitions Related to Manufactured Homes....3-8

3.5 General NFIP Floodplain Management Requirements for Manufactured Homes....3-9

3.6 NFIP Requirements for Manufactured Homes in Riverine and Inland Flood Zones....3-10

3.6.1 Approximate A Zones....3-11

3.6.2 Elevation in A, A1-30, AE, and AH Zones....3-13

3.6.3 3-Foot Pier Foundation....3-14

3.6.4 Elevation in Zone AO....3-16

3.6.5 Anchoring....3-17

3.6.6 Flood Damage-Resistant Materials....3-18

3.6.7 Utilities and Mechanical Equipment....3-18

3.6.8 Enclosed Areas....3-19

3.6.9 Floodways....3-20

3.7 NFIP Requirements for Manufactured Homes in Coastal Flood Areas....3-22

3.7.1 Elevation and Anchoring....3-23

3.7.2 Fill....3-25

3.7.3 Enclosed Areas and Breakaway Walls....3-25

3.7.4 Setbacks....3-26

3.8 Existing Manufactured Homes in Flood Hazard Areas....3-27

3.8.1 Relocation....3-27

3.8.2 Evacuation....3-28

3.8.2.1 Manufactured Home Substantially Improved or Returned to a Different Site or Pad in an Existing Manufactured Home Park....3-29

3.8.2.2 Manufactured Home Placed in a New Manufactured Home Park or Subdivision....3-30

3.9 HUD Manufactured Home Construction and Safety Standards 3-30
3.10 HUD Model Manufactured Home Installation Standards 3-32
3.11 Model Building Code Requirements 3-34
3.11.1 IRC 2006 3-34
3.11.2 NFPA 5000 3-35
3.11.3 NFPA 501 3-36
3.11.4 NFPA 225 3-36

4 Site and Development Options 4-1
4.1 Step 1: Compiling Site Information 4-2
4.2 Step 2: Reviewing Basic Siting Information 4-4
4.3 Step 3: Hazard Analysis and Risk Assessment 4-4
4.3.1 Flooding 4-5
4.3.1.1 Accessibility 4-6
4.3.2 Other Hazards 4-8
4.4 Step 4: Protecting Properties In and Near Hazard-Prone Areas 4-10
4.4.1 Placement Options 4-10
4.4.1.1 Flood-Prone Areas 4-10
4.4.1.2 Areas Subject to Landslides 4-12
4.4.2 Design and Construction Techniques 4-12
4.4.2.1 Flood-Prone Areas 4-12
4.4.2.2 Dam Failure Inundation Areas 4-12
4.4.2.3 Areas Subject to Landslides 4-13
4.4.2.4 Areas Subject to Seismic Events 4-13
4.4.2.5 Areas Subject to Wind/Debris Hazards 4-13
4.5 Step 5: Deciding on Property Development: Proceed or Reject 4-13

5 Natural Hazards – Design Considerations 5-1
5.1 Flood Data 5-1
5.2 Flood Characteristics 5-5
5.2.1 Frequency, Duration, and Rate of Rise 5-5

5.2.2 Flood Elevation and Depth 5-7
5.2.3 Hydrostatic (Buoyancy) Forces 5-8
5.2.4 Hydrodynamic Forces 5-9
5.2.5 Erosion and Scour 5-12
5.2.6 Debris Impact Forces 5-13
5.3 Wind 5-14
5.3.1 Wind Forces on Structures 5-15
5.3.2 Wind Forces in Combination with Flood Forces 5-15
5.4 Earthquakes 5-16
5.4.1 Design Philosophy 5-16
5.4.2 Design Standard 5-16
5.5 Evaluation of Multi-Hazards 5-17
5.5.1 Load Combinations (ASCE 7) 5-18
5.5.1.1 Strength Design (Load and Resistance Factor Design) 5-18
5.5.1.2 Allowable Stress Design (also known as Working Stress Design) 5-19
6 Soils 6-1
6.1 Bearing Capacity 6-1
6.2 Effects of Flood Duration and Frequency on Soil 6-2
6.3 Soil Liquefaction 6-2
6.4 Recommended Soil Testing and Criteria for Manufactured Home Installations 6-3
7 Ground Anchors 7-1
7.1 Types of Anchors and Installed Configurations 7-2
7.1.1 Types of Anchors 7-2
7.1.1.1 Helical Earth Anchors 7-2
7.1.1.2 Concrete Anchors 7-2
7.1.1.3 Cross Drive Anchors 7-2
7.1.2 Anchor Construction and Capacity 7-3
7.1.3 Anchor Selection 7-3

7.1.4 Anchor Installation 7-4
7.1.5 Anchor Performance 7-5
7.1.6 Anchors and Other Foundation Elements 7-8
7.2 FEMA Anchor Test Program 7-8
7.2.1 Anchors in Saturated Soils 7-8
7.2.2 Anchor Test Results 7-9
7.3 Recommended Ground Anchor Certification, Performance, and Design Values 7-11
7.3.1 Recommended Ground Anchor Certification Performance 7-11
7.3.2 Recommended Ground Anchor Design Values 7-11
7.4 Ground Anchors in Seismically Active Areas 7-13
8 Foundation Systems 8-1
8.1 Introduction 8-1
8.2 Enclosed Foundations 8-2
8.3 Open Foundations and Breakaway Walls 8-3
8.3.1 Pier Systems 8-3
8.3.1.1 Reinforced Pier Systems 8-4
8.3.1.2 Unreinforced Pier Systems 8-5
8.3.2 Pile Foundations 8-7
8.4 Bracing 8-9
8.5 Footings 8-10
8.6 Foundation Materials Selection 8-11
8.6.1 Wood Foundations 8-12
8.6.2 Concrete Foundations 8-12
8.6.3 Steel Foundations 8-13
8.6.4 Masonry Foundations 8-13
8.7 Foundation Selection and Flood Resistance 8-13
8.7.1 Flooding Types 8-14
8.7.2 Flood Characteristics 8-14
8.7.3 Flood Hazard Zones 8-15

8.7.4 Proximity to Flood Source 8-15

8.7.5 Foundation Selection Guidance 8-16

9 Recommended Design Process and Criteria for Manufactured Home Foundations in SFHAs 9-1

9.1 Performance Criteria 9-1

9.2 Design Criteria 9-1

9.3 Design Process 9-2

9.3.1 Step 1: Determine Design Criteria 9-3

9.3.2 Step 2: Select a Design Methodology and Assess Load Combinations and Failure Modes 9-4

9.3.2.1 Design Methodology 9-4

9.3.2.2 Load Combinations 9-4

9.3.2.3 Primary Failure Modes 9-4

9.3.3 Step 3: Select Foundation Type and Material 9-5

9.3.4 Step 4: Determine Forces at Connections and on Foundation Components 9-6

9.3.5 Step 5: Specify Connections and Framing Methods Along with Component Dimensions to Satisfy Load Conditions 9-6

9.3.6 Step 6: Note All Design Assumptions and Details on Drawings 9-6

10 Recommended Foundations 10-1

10.1 Design Criteria for Recommended Foundations 10-1

10.1.1 Reinforced Masonry Perimeter Foundation Walls 10-2

10.1.2 Wood Framed Perimeter Foundation Walls 10-3

10.1.3 Braced Masonry Pier Designs 10-3

10.1.4 Wood H-Frame Designs 10-4

10.1.5 Ground Anchor Designs 10-4

10.2 Summary of Recommended Foundations 10-5

10.3 Floodwater Velocity Design Considerations for Pier Foundations 10-6

10.4 Recommended Foundation Designs for Seismic Areas 10-7

10.4.1 Concrete Masonry Pier Foundation Designs 10-7

10.4.2 Masonry Wall Foundation Designs 10-7

10.4.3 Wood Framed Foundation Designs 10-8

10.5 Design Drawings 10-8

Appendices

Appendix A: References

Appendix B: Sources for Flood Information

Appendix C: Flood Velocity Determination

Appendix D: Definitions

Appendix E: Acronyms and Abbreviations

Appendix F: Example Calculations

Appendix G: Wind Zone Comparisons (HUD's MHCSS and ASCE 7-05)

Appendix H: Pre-Engineered and Prescriptive Foundation Designs

Figures

Chapter 1

Figure 1-1. Basic wind zone map for manufactured housing. 1-4

Figure 1-2. Inadequate turnbuckle anchor installed by the homeowner on this pre-1994 manufactured home, coupled with lack of elevation and an unreinforced foundation system, led to severe damage. 1-7

Figure 1-3. The addition to this manufactured home was destroyed, causing considerable damage to the rest of the home. 1-7

Figure 1-4. Reinforced masonry pier foundation system under a manufactured home installed after 1994 that performed well. 1-8

Figure 1-5. Manufactured home in Cudjoe Key, Florida, built and installed after 1994, survived Hurricane Georges with only minor damage caused by the loss of an awning. 1-8

Chapter 2

Figure 2-1. Traditional chassis system. 2-2

Figure 2-2. Integrated floor system consisting of steel-reinforced perimeter framing. 2-2

Figure 2-3. Main construction features of a typical manufactured home. 2-4

Figure 2-4. One section of a double-section manufactured home being transported. 2-5

Figure 2-5. Typical installation of a manufactured home on masonry block piers with tie-down straps. 2-6
Figure 2-6. Typical installation of a double-section manufactured home on a pier and ground anchor foundation system. 2-6
Figure 2-7. Perimeter wall foundation under a manufactured home. 2-7
Figure 2-8. Utility line damage in unstable soils. 2-9

Chapter 3

Figure 3-1. Sample DFIRM. 3-4
Figure 3-2(a). Sample FIS Summary of Discharges table. 3-5
Figure 3-2(b). Sample FIS Floodway Data 3-5
Figure 3-2(c). Sample FIS Flood Profile. 3-6
Figure 3-3. Manufactured home with lowest floor elevated to the BFE. 3-14
Figure 3-4. Manufactured home on reinforced pier foundation 36 inches high. 3-16
Figure 3-5. DFIRM showing the floodway (cross-hatched area in Zone AE). 3-21
Figure 3-6. Manufactured home with the bottom of the lowest horizontal structural member elevated to the BFE. 3-24
Figure 3-7. Mean high tide line development restriction. 3-27
Figure 3-8. Coastal development well-suited to the land: generous setbacks, in combination with deep lots and avoidance of dune areas, should afford protection from erosion and flooding for years to come. 3-27
Figure 3-9. Certification plate for manufactured homes built after June 15, 1976. 3-31

Chapter 4

Figure 4-1. Portions of an FIS and a FIRM. 4-7
Figure 4-2. Floodplain/floodway schematic. 4-11

Chapter 5

Figure 5-1. Example of a FIRM. 5-2
Figure 5-2. FIS Summary of Discharges table. 5-3
Figure 5-3. FIS Stream Flood Profile. 5-4
Figure 5-4. FIS Floodway Data table. 5-4
Figure 5-5. Buoyancy forces acting on a structure. 5-9
Figure 5-6. Failure due to sliding. 5-10
Figure 5-7. A manufactured home destroyed by the hydrodynamic forces of flooding. 5-10
Figure 5-8. Failure of a modular home due to high winds. The home lifted off of its foundation (concrete slab) when the connections failed. 5-14

Figure 5-9. A manufactured home that failed during a high-wind event. 5-15

Chapter 7

Figure 7-1. Cross drive anchor. 7-2
Figure 7-2. Single and double helix ground anchors with strap connection and single helix anchor with a closed-eye connection. 7-3
Figure 7-3. Electric anchor drive machine. 7-4
Figure 7-4. Typical ground anchor installation. 7-5
Figure 7-5. In line ground anchor installation. 7-6
Figure 7-6. Typical response for an axially loaded anchor. 7-7
Figure 7-7. Typical response for a non-axially loaded anchor used with a stabilizer plate. 7-8
Figure 7-8. Failed foundation system that used masonry piers. 7-9
Figure 7-9. Three graphics showing the anchor configurations described in Tables 7-2 and 7-3. 7-11

Chapter 8

Figure 8-1. A manufactured home elevated on a perimeter foundation wall. 8-2
Figure 8-2. Reinforced masonry and concrete piers 8-5
Figure 8-3. Bolted connection between frame and reinforced pier. 8-6
Figure 8-4. Manufactured home on a pile foundation. 8-7
Figure 8-5. Pile driving methods 8-8
Figure 8-6. Diagonal bracing. 8-10
Figure 8-7. Knee bracing. 8-10

Chapter 9

Figure 9-1. A home that was partially submerged and displaced from its foundation by hydrostatic forces. 9-5

Tables

Chapter 3

Table 3-1. Common SFHA Designations for Riverine or Inland Flood Zones 3-6
Table 3-2. Common SFHA Designations for Coastal Flood Areas 3-6

Chapter 4

Table 4-1. Information Checklist 4-2
Table 4-2. Partial Listing of Local, Regional, and State Responsibilities 4-4

Table 4-3. Flood Hazards....4-5
Table 4-4. Hazard-Prone Areas....4-9

Chapter 5

Table 5-1. Sources for Information About Past Flood Events....5-6
Table 5-2. Load Combination Nomenclature (ASCE 7)....5-17

Chapter 7

Table 7-1. Soil Classifications Using a Standard Torque Probe (STP)....7-4
Table 7-2. Dry Site Anchor Data....7-10
Table 7-3. Wet Site Anchor Data....7-10
Table 7-4. Recommended Design Loads – from FEMA Ground Anchor Testing Program....7-12
Table 7-5. Recommended Design Stiffness for Tested Anchors....7-12

Chapter 8

Table 8-1. Recommended Manufactured Home Foundation Selection for Lake/Pond Flooding (for very low velocity less than 1 fps)....8-16
Table 8-2. Recommended Manufactured Home Foundation Selection for Riverine Flood Zones (and maximum flood flow velocity)....8-17
Table 8-3. Recommended Manufactured Home Foundation Selection for Coastal Flood Zones....8-18

Chapter 9

Table 9-1. Design Standards and Publishers for Building Materials....9-6

Chapter 10

Table 10-1. Summary of Recommended Foundations....10-5
Table 10-2. Design Flood Flow Velocity for Concrete Masonry Unit Foundations....10-6
Table 10-3. Foundation Drawings....10-8

1 Introduction

This revised edition of FEMA 85 provides new recommendations for manufactured home foundation design and installation. The initial 1985 edition of FEMA 85 provided guidance on installation methods designed to make manufactured homes less susceptible to damage caused by flood and wind events. Significant advances in design and construction technologies, mitigation strategies, and regulatory requirements since 1985 have all contributed to the need for updated guidance.

1.1 Purpose and Scope of the Guide

Like the original guide, this updated version of FEMA 85 focuses primarily on the installation and foundation requirements for manufactured homes in floodplains for communities participating in the National Flood Insurance Program (NFIP). However, it also addresses other natural hazards such as high winds and earthquakes.

The purpose of the second edition of FEMA 85 is to provide guidance for the design and construction of alternative foundation systems as described in the HUD *Model Manufactured Home Installation Standards* (24 CFR 3285). It is important to recognize that both the U.S. Department of Housing and Urban Development (HUD) and the NFIP require that foundation systems for manufactured homes located in Special Flood Hazard Areas (SFHAs) prevent flotation, collapse, or lateral movement of the structure (24 CFR 3285.302 and 44 CFR 60.39(a)(3), respectively).

The manufactured housing industry has adopted the term "community" for manufactured home developments. However, the term "park" is used in the NFIP and is also used in this publication.

With its broad and comprehensive scope, this document provides guidance on siting and installing manufactured homes in areas exposed to natural hazards. The guide is organized into 10 chapters, each covering a different aspect of manufactured homes in the United States, and 8 appendices.

Chapter 1 provides a historical overview of Federal, State, and local regulations that affect the design, construction, and installation of manufactured homes, including guidance on the NFIP and HUD installation requirements.

Chapter 2 presents and defines the characteristics of a manufactured home, the types of foundations used, typical installation techniques, and additional design considerations of attachments to manufactured homes (e.g., carports, decks, porches, and awnings).

Chapter 3 provides the regulatory requirements pertaining to the installation of manufactured homes in flood-prone areas. NFIP, HUD and model building code requirements are discussed as well as methods for mitigating manufactured homes (e.g., elevation and relocation).

Chapter 4 presents issues to consider in the siting of manufactured homes.

Chapter 5 provides a review of natural hazards that must be considered in site selection, foundation design, and installation of manufactured homes. The discussion covers flooding, including the special hazards associated with coastal flooding (e.g., storm surge, velocity flow, and wave impact), high winds, and seismic events. The combined effects of multiple hazards are also covered.

Chapter 6 contains a review of the geology and hydrology of soils and their effects on manufactured home foundation systems. Soil characteristics and the behavior of saturated soils are discussed. Recommendations are provided for soil testing criteria applicable for manufactured home installation.

Chapter 7 presents a review of the use of ground anchors with manufactured home foundations, including the results of laboratory and field tests of anchor performance in saturated soils.

Chapter 8 presents different types of manufactured home foundation systems, including their performance, installation procedures, maintenance requirements, and possible modifications. Systems discussed include pier systems that incorporate ground anchors, braced piers and piles, slabs, elevated floors or crawlspaces, and proprietary systems.

Chapter 9 discusses recommended design processes and criteria for manufactured home foundations in SFHAs. Recommended design criteria, performance requirements, and best practice recommendations are presented. Sites that fall outside of the criteria specified for recommended foundations in Chapter 10 can use the design process detailed in this chapter.

Chapter 10 provides design criteria for recommended foundations appropriate for typical installation of manufactured homes in flood zones designated A, AE, A1-A30, A0, or AH on a FEMA Flood Insurance Rate Map (FIRM). Criteria are presented regarding maximum flood depth, flow velocity, wind speed, and seismic force. The designs are shown in Appendix H.

The appendices include:

A: References

B: Sources for Flood Information

C: Flood Velocity Determination

D: Definitions

E: Acronyms and Abbreviations

F: Example Calculations

G: Wind Zone Comparisons

H: Pre-Engineered and Prescriptive Foundation Designs

The foundation designs discussed in Chapter 10 and shown in Appendix H are but one of a group of acceptable foundation solutions. They should not be considered mandatory or all

inclusive. Any modifications to the foundation drawings must be designed and approved by a licensed professional engineer. Alternative foundation systems designed to resist equivalent loads and to provide equivalent performance should be considered equally acceptable.

Flowcharts, checklists, maps, formulas, and drawings are provided throughout the guide to help in understanding the issues to consider when installing a manufactured home in a floodplain. Examples are presented to demonstrate decisions and calculations designers must make to reduce the potential damage to manufactured homes from natural hazard events.

1.2 Background

1.2.1 Manufactured Homes in the United States

Manufactured homes help fill a demand for affordable housing in many parts of the United States. In 2007, the U.S. Census reported that the industry shipped 95,700 homes with an average price of $64,500. Single-section homes had an average price of $35,200, and double-section homes had an average price of $73,100. U.S. Census Bureau figures from Census 2007 show that 74 percent of new manufactured homes were located on private properties and 26 percent were located in manufactured home parks. The average floor area of a manufactured home placed in 2007 was approximately 1,600 square feet. Approximately 31 percent of the manufactured homes placed in 2007 were located in four States (Florida, California, Louisiana, and Texas).

Since 1976, the NFIP has regulated the installation of manufactured homes in floodplains. Over the years, the NFIP has strengthened the regulations by defining existing and new manufactured home parks and applying differing standards for each. The standards governing manufactured homes continue to improve; Federal, State, and local governments and the manufactured home industry strive to institute construction practices and regulations to increase the safety of manufactured homes in natural hazard environments. The following list summarizes regulations, programs, and actions that have been developed to improve the resistance of manufactured homes to natural hazards:

- On July 13, 1994, HUD adopted new structural resistance guidelines for the construction of manufactured homes to be placed in HUD Wind Zones II and III (Figure 1-1).
- Section 605 of the National Manufactured Housing Construction and Safety Standards Act of 1974 (42 U.S.C. 5401), as amended by the Manufactured Housing Improvement Act of 2000, authorized the Secretary of HUD to establish and implement a national manufactured housing installation program to include (1) installation standards, (2) the training and licensing of manufactured home installers, and (3) the inspection of manufactured home installations.

States may choose to operate an installation program for manufactured homes in lieu of the Federal program. The State must implement standards that provide protection to its residents that equals or exceeds the *Model Manufactured Home Installation Standards* (24 CFR 3285.1(a)(1). See http://www.hud.gov/offices/adm/hudclips for more information.

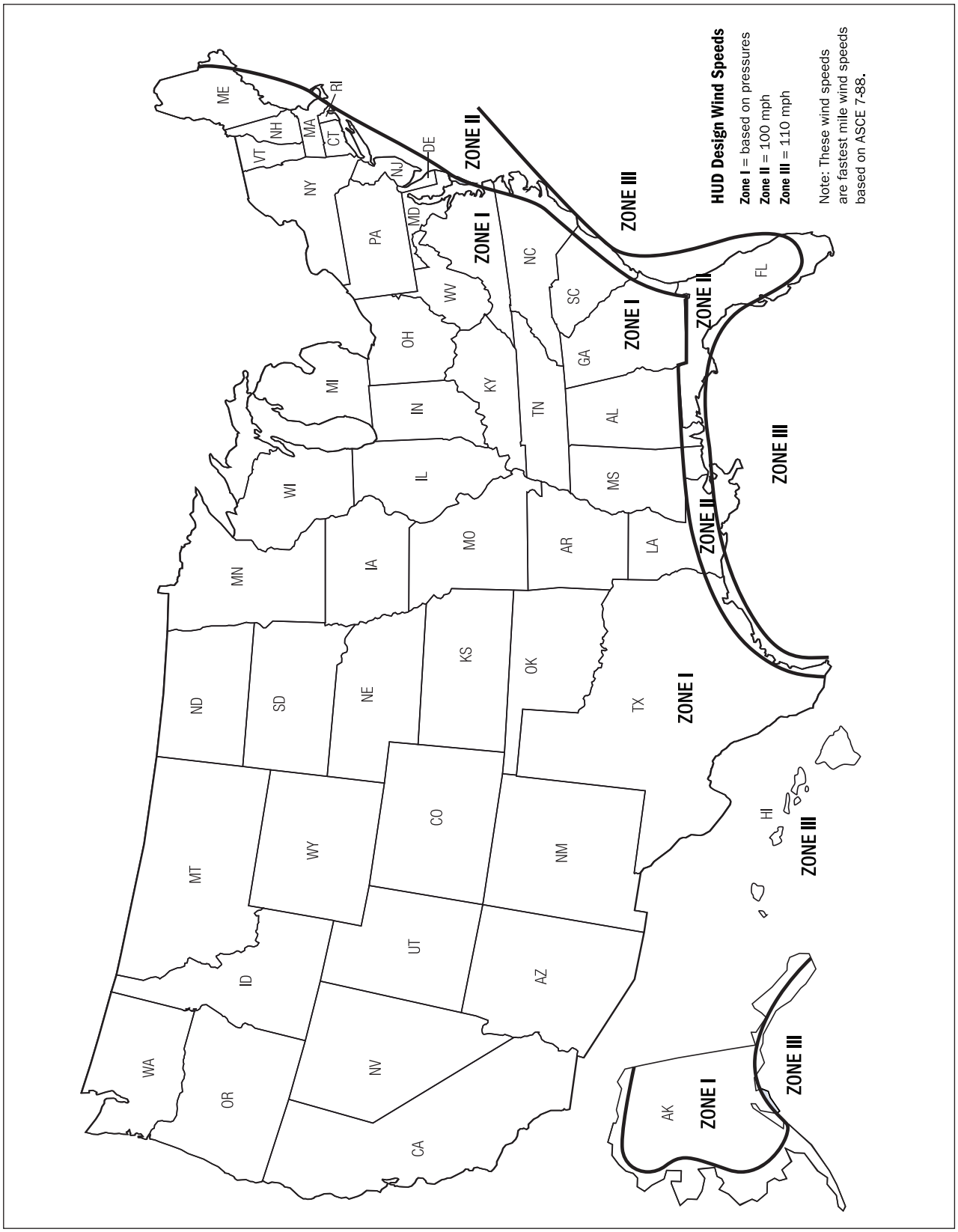


Figure 1-1. Basic wind zone map for manufactured housing.

- Installation program requirements have been established under 24 CFR 3286, *Federal Manufactured Home Installation Program* effective October 20, 2008. Compliant training and licensing programs for installation and inspections are being implemented in all States.
- The National Fire Protection Association (NFPA) has published three documents on the subject of manufactured housing:
  - NFPA 501, *Standard on Manufactured Housing*
  - NFPA 501A, S*tandard for Fire Safety Criteria for Manufactured Home Installations, Sites and Communities*
  - NFPA 225, *Model Manufactured Home Installation Standard*, which will, in adopted areas, govern installation of manufactured homes.
- The National Technology Transfer Act of 1995 included a goal that Federal agencies use technical standards developed or adopted by voluntary consensus standard bodies. Although HUD has recognized NFPA as a consensus standard developing body, HUD is not obligated to use standards developed by that body.
- Several States and localities, including Florida and North Carolina, have strong installation standards, which include requiring manufactured homes to meet State and local building code requirements; a manufactured home installer education, testing, and certification program for HUD homes; and aggressive inspection programs to ensure proper installation.

1.2.2 National Flood Insurance Program

The U.S. Congress established the NFIP with the passage of the National Flood Insurance Act of 1968, as amended. The NFIP is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages. Participation by communities in the NFIP is based on an agreement between communities and the Federal Government. If a community adopts and enforces floodplain management regulations to reduce future flood risks to new construction in floodplains, the Federal Government will make flood insurance available within the community as a financial protection against flood losses. Participation in the NFIP by communities is voluntary.

Federal flood insurance is designed to provide an alternative to disaster assistance and disaster loans for home and business owners. Disaster assistance rarely comes close to covering all of the costs to repair and cleanup. While available to qualified victims, disaster loans do not significantly ease the financial burden due to repayment terms. It is important to remember that disaster assistance is available only after floods have been declared major disasters by the President of the United States. In contrast, insurance claims will be paid any time damage from a qualifying flood event occurs.

Another important objective of the NFIP is to break the cycle of flood damage. Many buildings have been flooded, repaired, or rebuilt, and flooded again. In some parts of the country, this cycle occurs every couple of years; people rebuilt in the same flood-prone areas and used the

same construction techniques that did not adequately protect the structure. By encouraging communities to guide development to lower risk areas, and by requiring the elevation of new buildings and older nonconforming buildings that are subject to flood damage, one of the long-term objectives of the NFIP can be achieved: reducing flood damage and losses. Older buildings may be removed or replaced, or they may be upgraded or modified with techniques that lead to little or no future flood damage.

The NFIP is administered by the Federal Emergency Management Agency (FEMA), which is part of the Department of Homeland Security (DHS).

In order to participate in the NFIP, communities must adopt minimum floodplain management requirements that meet or exceed the minimum requirements of the NFIP. Communities can adopt NFIP floodplain management requirements through building codes, zoning ordinances, subdivision regulations, health and safety codes, and stand-alone floodplain ordinances.

NFIP regulations have specific floodplain management requirements for manufactured homes located in a SFHA. In general, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. At sites having a base flood elevation (BFE) identified for Zones A1-30, AH, or AE on the community's FIRM, NFIP regulations generally require that manufactured homes be elevated on a permanent foundation such that the lowest floor is at or above the BFE, and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement. At sites having a BFE identified for Zone VE on the community's FIRM, NFIP regulations require that manufactured homes be elevated on pilings and columns so that the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE. More detailed information pertaining to the NFIP requirements for manufactured homes installed in flood hazard areas is provided in Chapter 3.

1.2.3 Performance of Manufactured Homes in Wind and Flood Events

1.2.3.1 Performance of Pre-1994 Manufactured Homes

In 1992, Hurricane Andrew struck Dade County, Florida, destroying 97 percent of the manufactured homes in its path. In 1994, in response to the devastating damage, HUD adopted more stringent wind design criteria for manufactured homes installed in HUD Wind Zones II and III. Provisions for doors and windows more resistant to wind pressures were required. Although numerous hurricanes have made landfall in the U.S. since 1994, none have produced winds that approached those of Hurricane Andrew. In 1998, Hurricane Georges caused damage throughout Monroe County (the Florida Keys), Florida. FEMA dispatched a Building Performance Assessment Team (BPAT) to report on the performance of manufactured housing in impacted areas. Most of the damage observed occurred to homes installed before Monroe County had adopted the NFIP regulations that required new and substantially damaged manufactured homes located in SFHAs be elevated to the BFE and anchored to resist flotation, collapse, or lateral movement.

Most of the flood damage caused by Hurricane Georges to the manufactured homes constructed before 1994 was the result of a lack of adequate elevation, the use of unreinforced piers

(dry-stacked blocks) in areas exposed to moving floodwaters, inadequate anchoring, and failure of attached site-built additions (Figures 1-2 and 1-3). Anchoring failure problems included poorly attached anchors; lack of corrosion-resistant materials; homes not fastened to their support piers; and improperly attached tie-down straps.

Figure 1-2. Inadequate turnbuckle anchor installed by the homeowner on this pre-1994 manufactured home, coupled with lack of elevation and an unreinforced foundation system, led to severe damage.

Figure 1-3. The addition to this manufactured home was destroyed, causing considerable damage to the rest of the home.

1.2.3.2 Performance of Post-1994 Manufactured Homes

The lessons learned from Hurricane Andrew in Florida have resulted in manufactured homes being built stronger and installed more solidly; thus these homes are able to better resist extreme loading (in particular, flood and wind loads).

Figure 1-4 shows the success of the reinforced masonry pier foundation of a manufactured home installed after 1994. Although the area experienced moving floodwaters fast enough to displace the air conditioning compressor shown under the home and create localized erosion and scour, the reinforced masonry piers survived without damage.

The manufactured home shown in Figure 1-5, on Cudjoe Key in Monroe County, was built to the 1994 standards. It survived Hurricane Georges with only minor damage.

Figure 1-4. Reinforced masonry pier foundation system under a manufactured home installed after 1994 that performed well.

Figure 1-5. Manufactured home in Cudjoe Key, Florida, built and installed after 1994, survived Hurricane Georges with only minor damage caused by the loss of an awning. The older manufactured home on the lot next door was destroyed by high winds and coastal surge.

1.2.3.3 Performance of Manufactured Homes During Hurricane Charley (2004) in Florida

Based on field observations, the Hurricane Charley Mitigation Assessment Team (MAT) provided the following conclusions in their report as related to the performance of manufactured homes:

"Finally, performance of manufactured housing was also observed to be a function of age of the building and the regulations to which the units were designed, constructed, and installed. Widespread damage was observed to manufactured housing designed and constructed prior to the 1976 HUD regulations. The performance of units installed between 1976 when the first HUD regulations were enacted and the implementation of the 1994 HUD regulations was observed to be somewhat improved, but significant improvements in performance were observed in the units designed and installed to the HUD regulations implemented after 1994 in response to Hurricane Andrew. Although some instances of structural failure were observed, the newer manufactured housing units typically sustained minimal structural damage and remained secured to their foundations when installation followed State requirements (e.g., enforced by the Division of Motor Vehicles, Department of Highway Safety and Motor Vehicles, etc.) of unit tie-downs (anchors) at 5 feet, 4 inches on-center (if no ancillary structures were attached to the unit). Much of this improved performance was difficult to observe due to widespread damage caused by the failures of improperly designed and constructed attached structures (including screen enclosures, carports, and accessory structures). The failure of these attached structures, in many places occurring where wind speeds were below the design wind speed for the area, resulted in extensive damage to roof coverings, siding, windows, and doors of the manufactured units, and generated significant amounts of debris. Very few manufactured homes had glazing protection and, as a result, numerous unprotected windows on units along the path of the eye of the storm were damaged and broken. Had the [HUD design wind speed] Zone II and Zone III homes installed in areas where debris protection is required for site-built one- and two-family dwellings been shipped with appropriate glazing protection, these homes [within the path of Hurricane Charley] would have been protected from windborne debris."

2 Manufactured Homes

2.1 Manufactured Home Characteristics

Manufactured homes are one of several types of homes constructed entirely or partially in an off-site factory, transported over roadways, and then placed or assembled on a site-built foundation. After the home is in position, utilities (e.g., water, sewer, electric) are connected, ancillary components (e.g., siding, skirting) are installed, and the home is ready for habitation. Factory built homes include manufactured homes, modular homes, panelized homes, and pre-cut homes.

Modular, panelized, and pre-cut homes must comply with the same State and local building codes as "site stick built" codes. Manufactured homes must meet HUD regulations.

HUD regulations for manufactured homes are contained in 24 CFR 3280, *Manufactured Home Construction and Safety Standards* (MHCSS), and 24 CFR 3285, *Model Manufactured Home Installation Standards* (collectively referred to as the HUD codes). HUD regulations define manufactured housing as:

> "..a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities" (24 CFR 3280.2 and 24 CFR 3285.5)

2.1.1 Chassis Support System

Manufactured homes are constructed on a chassis consisting of main steel beams and cross members; fitted axles, leaf springs, and wheels making up the running gear; and a steel hitch assembly. After the home is sited, the chassis frame distributes the manufactured home loads to the foundation system. The hitch assembly is generally removed for appearance purposes.

There are two general chassis designs. The traditional chassis system consists of two longitudinal steel beams (between 10 and 12 inches deep); steel cross members that span between the beams; and steel "outriggers" extend beyond the beams to support exterior walls of the home (Figure 2-1). Manufactured homes designed to be placed on perimeter foundation walls often are manufactured with shorter outriggers to provide clearance for the site-built foundation walls.

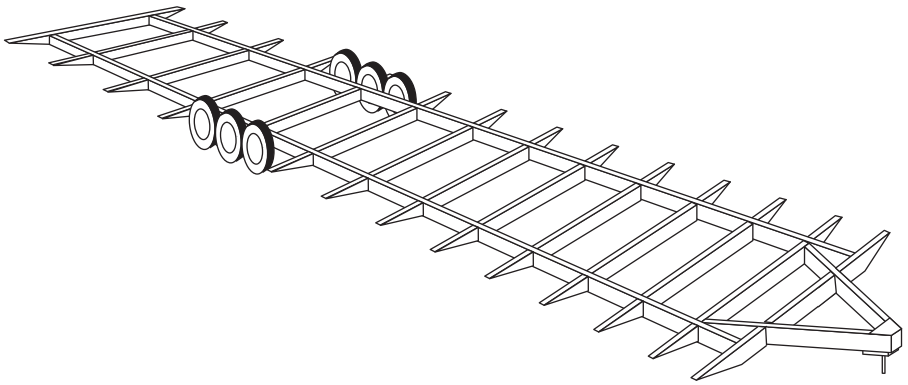


Figure 2-1. Traditional chassis system.

2.1.2 Integrated Support System

An alternative configuration relocates the steel main beams to the perimeter of the home, eliminating the cantilever "outriggers" (Figure 2-2).

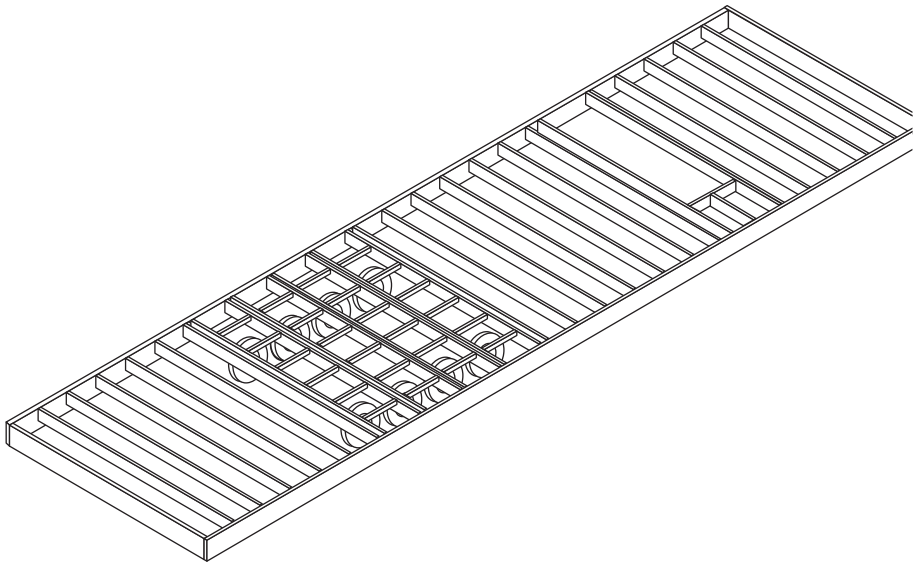


Figure 2-2. Integrated floor system consisting of steel-reinforced perimeter framing.

Source: *Manufactured Home Producer's Guide to the Site-Built Market*, HUD.

2.1.3 Envelope Construction

The manufactured home envelope must be designed to meet MHCSS (24 CFR 3280) strength and rigidity requirements. The floor decking material, attached to the floor joists, is usually wood composite panels or plywood. Floor joists spanning between steel cross beams generally are spaced at 16-inch centers. Exterior wall frames generally are constructed with wood studs, and the exterior of the home is generally covered with vinyl, aluminum, or wood siding. Common wood stud dimensions used in HUD Code housing are typically 2 inches wide by 3 inches deep, or 2 inches wide by 4 inches deep based on the design vertical and lateral loads. Some designs for manufactured homes located in HUD Wind Zone III require the use of studs 2 inches wide by 6 inches deep.

Interior structural walls must have the structural capacity adequate for their intended use, with a minimum capacity to resist a horizontal load of 5 pounds per square foot (24 CFR 3280.305(f)(2). Interior wall frames typically use 2-inch by 3-inch wood studs. Interior non-structural walls can use 1-inch by 2-inch studs for framing.

The roof and ceiling system is typically constructed with prefabricated scissor trusses or other peaked trusses, sheathed with composite roof panels, underlayment, and shingles. Roof trusses typically are spaced at 24-inch centers.

Other construction features of manufactured homes include insulation, vapor barriers, gypsum wall and ceiling board, exterior roof and wall sheathing, doors and windows, and other finishing materials similarly found in site-built and modular homes. Figure 2-3 shows the main construction features of a typical manufactured home, including the envelope construction elements.

2.1.4 Double Section

A double-section manufactured home is constructed from two single floor sections and is, therefore, generally twice as wide as the normal 12- to 16-foot wide single-section unit. The design and construction of the chassis/floor system is comparable to that of the single-section unit. The double section is transported as two separate floor sections (Figure 2-4). The floor sections are then attached at the home's site. The area where the two floor sections come together is called the marriage line. Marriage beams, beam joists, and walls are properly aligned and connected at the site. The roof, walls, and floor along the marriage line must be properly aligned, sealed, and supported.

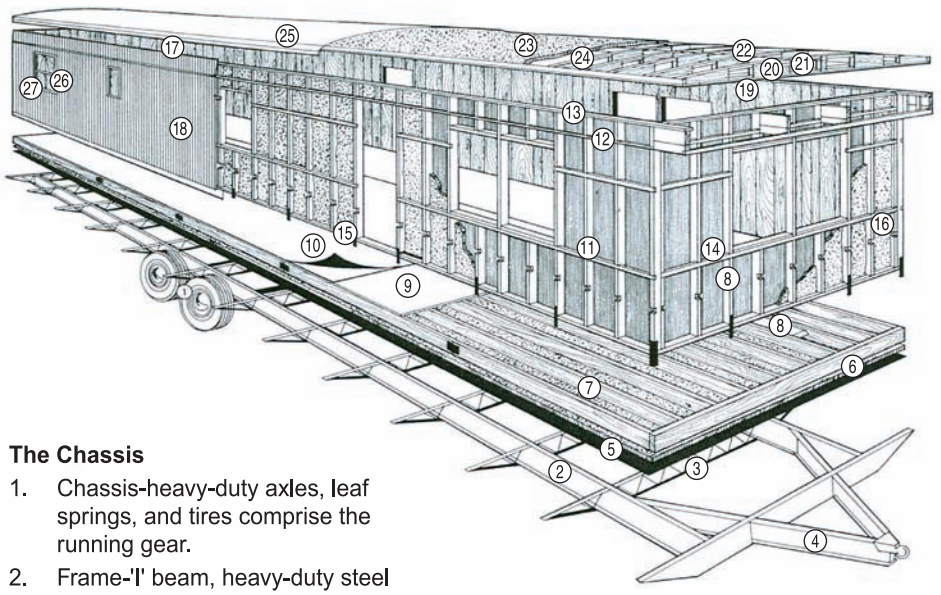
2.2 Types of Foundation Systems

Typical types of foundation systems used to support a manufactured home located in SFHAs include the following:

- Piers and ground anchors.
- Perimeter wall foundations.
- Proprietary foundation systems that transmit loads from the manufactured home to the ground using patented components or assemblies.

The HUD Codes (24 CFR 3285 Subparts D – Foundations and E – Anchorage Against Winds) provide design standards for pier foundations and anchor systems, including ground anchors. Alternative foundations must be manufactured and installed in accordance with their listings by a nationally recognized testing laboratory, based on a nationally recognized testing protocol, or be designed or tested by a registered professional engineer or architect in accordance with accepted engineering practice, and must not take the home out of compliance with the MHCSS (24 CFR 3285.301).

Figure 2-3. Main construction features of a typical manufactured home.



The Chassis

1. Chassis-heavy-duty axles, leaf springs, and tires comprise the running gear.
2. Frame-'I' beam, heavy-duty steel welded frames. 8", 10", or 12" "I" beams, depending on length of frame.
3. Rigid steel outriggers and center cross members.
4. Hitch – sturdy "I" beam hitch members optionally removable for cleaner appearance.

The Floor System

5. Bottom board tightly sealed on bottom of floor.
6. Floor insulation – all-weather insulation for temperature control, blanket fiberglass installed under entire floor for complete weatherproofing.
7. Floor joists.
8. Heat duct – aluminum-framed duct.
9. 5/8" decking particleboard glued and fastened to floor joists.
10. Roll goods-cushioned vinyl floor in non-carpeted areas.

The Wall System

11. 2" x 4" studs.
12. Dadoed belt rails for unitized sidewall construction.
13. 1" x 4" top and bottom plate.
14. Interior paneling – prefinished fire rated interior paneling glued and stapled to sidewall studs for unitized construction.
15. Rugged metal anchor bonding ties sidewalls to floor for additional strength.
16. Sidewall insulation – heavy-density fiberglass insulation.
17. Trim to harmonize with exterior decor.
16. Rigid exterior metal is prefinished aluminum with baked-on enamel finish.

The Roof/Ceiling System

19. Decorative ceiling board.
20. Gusseted truss-type rafters for extra roof strength.
21. Blanket fiberglass insulation between rafters.
22. Steel straps full length of roof over rafters support insulation and galvanized roof between rafters.
23. Thick fiberglass roll insulation over rafters.
24. Vapor barrier on warm side of roof to prevent condensation buildup.
25. Galvanized steel one-piece roof.

Windows and Doors

26, Large aluminum-framed windows with screens and optional storm windows.
27. Egress windows for emergency exit from every sleeping room.

Mechanical Service Systems

28. Electrical, plumbing, heating, and construction conform to or exceed the Federal Manufactured Home Construction and Safety Standards.

Figure 2-4. One section of a double-section manufactured home being transported.

Source: Manufactured Housing Institute.

Additional technical information on foundation systems for installation of manufactured homes is provided in Chapter 8 of this guide.

2.2.1 Typical Foundation Systems

2.2.1.1 Typical Installation

A manufactured home is typically placed on a site that has been stabilized and improved to provide adequate support for the home and anchoring system. Site and area improvements techniques vary widely across the country. Typical improvement techniques include simple ground stabilization (ground compaction), application of gravel, and/or construction of a concrete runner or slab.

Typical manufactured home foundations consist of a system of piers and ground anchors (refer to Section 2.2.1.2). Piers are typically placed beneath the two steel beams at a spacing of 8 to 10 feet along the length of the manufactured home. Frame ties are connected to the steel chassis or perimeter beams, and run to ground anchors (Figure 2-5) that are used with tie-downs and straps to secure a manufactured home in place. The frame ties and anchors provide lateral support; the piers provide vertical support.

Although typical manufactured home foundations and installation methods often address wind events, many give little consideration to the forces associated with flooding and seismic events. They generally are not designed for flood effects such as hydrodynamic and hydrostatic forces, buoyancy, erosion, and scour. Potential failure modes observed in a typical installation include:

- **Buoyancy**, particularly during rapidly rising floodwaters
- **Lateral movement**, particularly when exposed to moving floodwaters that extend above the home's steel beams

- **Pier collapse**, particularly when homes are exposed to wind and moving floodwaters simultaneously
- **Erosion and scour**, particularly when homes are exposed to high velocity floodwaters

2.2.1.2 Piers and Ground Anchors

Using both pier foundations and anchor assemblies together is the most common type of foundation system (Figure 2-6). Piers support the gravity loads of the home, and the anchors resist uplift and lateral loads. Piers are installed under the main beams of the home sections, under the marriage line of multi-section homes, and at locations designated by the home manufacturer. Common types of piers include several configurations of steel jack stands and stacked, reinforced or unreinforced hollow-core concrete masonry blocks of various configurations. Ground anchors, a specific anchoring assembly, typically consisting of auger-type (screw-in) ground anchors, are the most commonly used. The anchor is attached to the home's steel beams by steel straps. Chapter 7 discusses ground anchors in more depth.

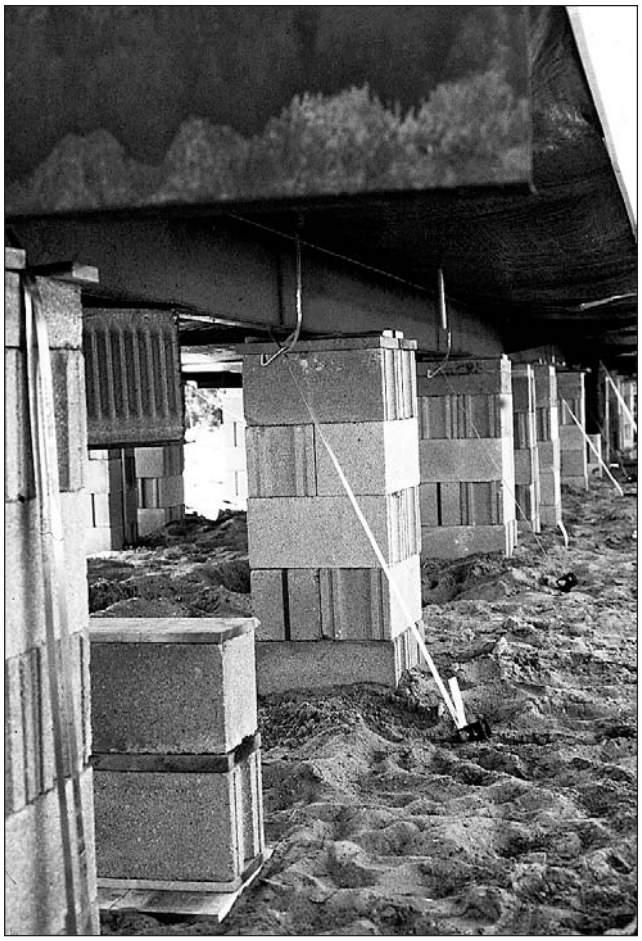


Figure 2-5. Typical installation of a manufactured home on masonry block piers with tie-down straps.

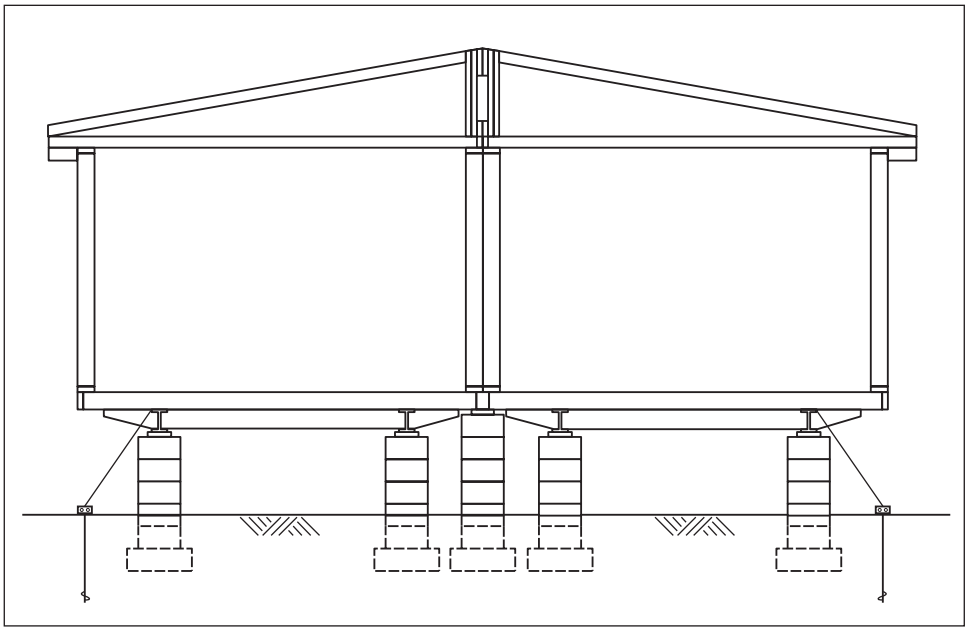


Figure 2-6. Typical installation of a double-section manufactured home on a pier and ground anchor foundation system.

The advantages of this foundation system are that it adapts easily to the site conditions, does not require much dimensional precision, is installed very quickly, and is economical to install.

2.2.1.3 Perimeter Wall Foundations

When perimeter foundations are used with a manufactured home constructed with chassis beams, the chassis beams provide support for gravity loads, and the perimeter walls resist uplift and lateral loads. When used with a manufactured home constructed with an integral floor framing system, the perimeter walls resist uplift, lateral, and gravity loads (Figure 2-7). With chassis systems, interior piers support the chassis, points along the marriage wall, and other areas of concentrated loads.

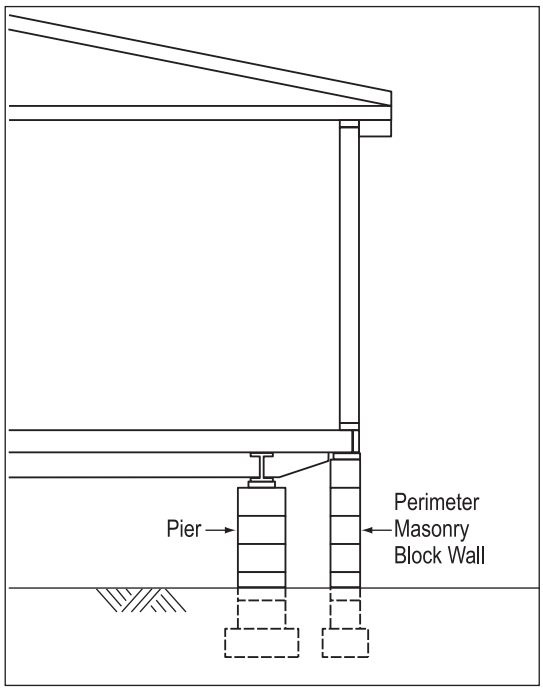


Figure 2-7. Perimeter wall foundation under a manufactured home.

Perimeter walls can be constructed with typical building materials (e.g., cast-in-place concrete, masonry, or preservative-treated wood); footings are generally cast-in-place concrete. Attaching the floor joists to the foundation wall provides resistance to horizontal and uplift forces.

Some considerations in using this system include the following:

- The system must be precisely measured and constructed before the home is delivered to the site.
- Typically, a crane or roller system will be needed to place the home onto the foundation.

The cost and construction time of this system is greater than the pier and ground anchor foundation system.

2.2.2 Proprietary Systems

A proprietary foundation is a patented system manufactured and sold only by the owner of the patent or licensee. If a proprietary system is selected for a manufactured home, it must be capable of resisting all design loads of the MHCSS, and those imposed by any site-specific natural hazards. (See the checklist on the next page for more information.)

The Systems Building Research Alliance (SBRA, formerly the Manufactured Housing Research Alliance [MHRA]) has evaluated proprietary and non-proprietary foundation systems for manufactured homes. Their publication, *Guide to Foundation and Support Systems for Manufactured Homes*, provides guidance for deciding among alternative foundation designs that are appropriate for a given site and budget. The SBRA is also continuing to conduct research foundation systems developed for use in SFHAs.

Proprietary Foundation System Checklist

- **Identify type of natural hazards for the manufactured home site.** Follow the steps in Chapter 9 of this guide.
- **Identify natural hazards design loads for the manufactured home.** Follow the steps in Chapter 9.
- **@eb`h abpfdk il^ap lk bkdfkbbofkd ao^t fkdp lo pmb`f^`^qflkp+** Design loads must be greater qe^k lo bnr^iql qeb il^ap fabkqf^ba fk Pqbm / lc @e^mqbo 6+
- **The drawing must have a professional engineer's or architect's seal,** ensuring the system was designed by a professional.

2.3 Utilities and Mechanical Equipment

2.3.1 Utilities Placement

Care needs to be taken in the placement of utilities (such as water, sewer, and gas services) and mechanical systems. Connecting the manufactured home to these utility and mechanical systems requires them to extend from the grade beneath the home up through the floor. Their location makes them susceptible to being inundated by floodwaters and damaged by floating debris. Therefore, separating these systems to protect them is important. To minimize damage to utility lines, they should be placed in waterproof risers located adjacent to the elevated foundation member on the downstream side of the expected (or anticipated) flood flow.

State and local codes and regulations must also be followed for utility services installations and connections. These provisions may require the waterproofing of all connections, the use of certain specific waterproof materials, and backflow preventers on water and sewage service. Underground telephone and electric service should also be enclosed in a riser and protected from damage in a similar manner. If electrical and telephone service is supplied from overhead lines, the service connection to the manufactured home must be located above anticipated flooding.

Special care must be taken in running underground utilities to homes. Differential movement between the home and utility can cause failure of the home to utility connection. Failures can cause electrical shock hazard or leakage of gas, water, or raw sewage. Similar problems can occur when utilities run through uncompacted backfill around a basement excavation or when utilities are subjected to seismic loads. Installing a flexible connection in the line is one way to reduce potential line breakage.

It is possible that a home with utility services could be displaced in a design wind or a seismic event. By design, ground anchors that are used to hold down many homes will displace on the order of 2 to 3 inches. Seismic forces can cause even higher displacements to utility connections than a design wind event (Figure 2-8). Therefore, some flexibility must be provided in the

utility lines to accommodate for any potential movements. Utility attachments to the manufactured home should be capable of accommodating the anticipated seismic and wind displacement of the support and anchorage system.

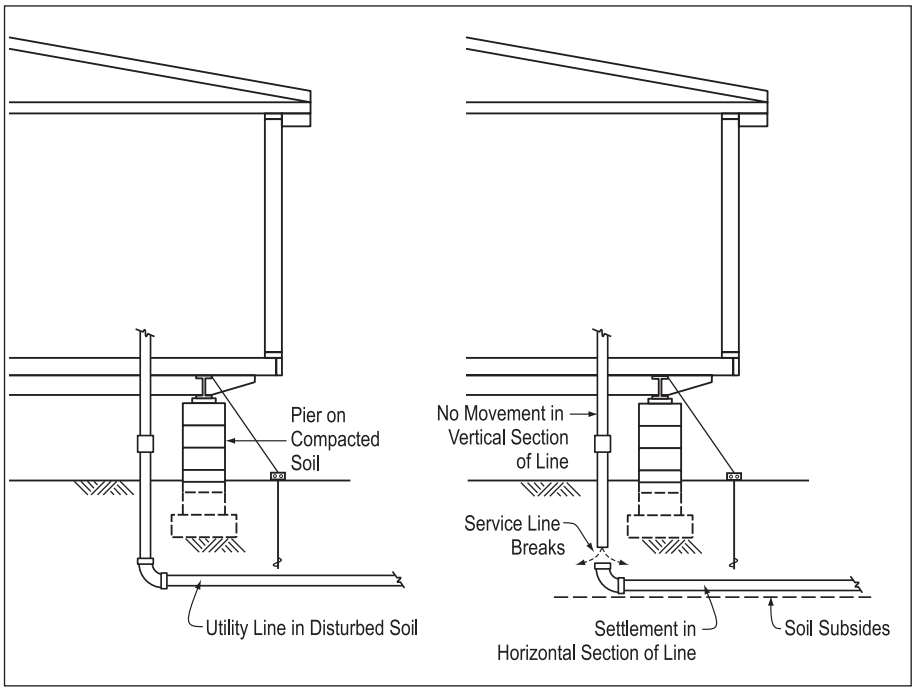


Figure 2-8. Utility line damage in unstable soils.

Propane and fuel oil tanks used to supply energy for heating or other services should be anchored against flotation or elevated above the anticipated flood level. Tank foundations should be separated from the home's foundation system. To minimize the potential for debris impact and damage, tanks and their supporting foundations should be located on the downstream side of homes. Bollards can be used to deflect floodborne debris and reduce the potential of impact damage. Additional information on utility systems for manufactured homes in the floodplain is provided in Section 3.6.7.

For manufactured homes located in seismic areas, site-installed water heaters should be provided with seismic bracing straps in accordance with the manufacturer's recommendations. Strapping a water heater to a wall to prevent it from falling over is an easy and cost-effective seismic mitigation measure. Other site-installed equipment weighing more than 100 pounds should be anchored to resist horizontal seismic forces.

2.3.2 Mechanical Access

Components of heating and air-conditioning systems installed within manufactured homes are generally located above the floor. When the home is elevated to the BFE, interior components are protected. However, components located below the floor remain vulnerable to flood damage. In particular, exterior heating and air conditioning compressors, and crossover ducts are common components that are damaged by floodwaters.

Compressor units can be elevated by placing them on platforms at the BFE; however, crossover ducts require the entire home to be elevated 1 to 2 feet above the BFE to prevent them from being damaged during the design flood.

2.4 Attachments – Carports, Decks, Porches, and Awnings

Carports, decks, porches, and awnings are often attached after the manufactured home has been installed. The HUD installation standard (24 CFR 3285.3) requires that attachments must not impose loads to the manufactured home or its foundations unless the attachments are included in the manufacturer's approved designs and installation instructions, or the attachments are designed by a registered engineer or architect consistent with the manufacturer's design. Similarly, the International Residential Code® (IRC®) requires that accessory buildings (e.g., carports, decks, porches, and awnings) shall not be structurally supported by or attached to a manufactured home unless engineering calculations are submitted to substantiate any proposed construction (IRC 2006 AE 504.1).

Carports, decks, porches, and awnings should only be built as stand-alone units. Additionally, if a stand-alone deck or porch is going to be added, design criteria for vertical foundation members on the addition should be equivalent to those for the foundation system of the main structure to prevent damage to the main structure from adjacent structures.

During the Hurricane Charley post-event assessment (2004), engineers noted the failure of these attached structures (in many places, occurring where wind speeds were below the design wind speed for the area), resulting in extensive damage to roof coverings, siding, and windows of the manufactured units, and generating significant amounts of debris.

3. Regulatory Requirements

Federal, State, and local regulatory requirements must be identified and assessed as an initial step in the installation of manufactured housing. The following discussion provides a summary of the applicable NFIP minimum requirements for the installation of manufactured homes in floodplains. In addition, HUD MHCSS and model building code requirements are summarized. Appendix A provides a list of publications for further guidance for the installation and placement of manufactured homes in hazard-prone areas.

3.1 Introduction to the NFIP

The NFIP has three main elements:

1. Flood insurance that provides financial protection for property owners to cover flood-related damage to buildings and contents.
2. Floodplain management requirements within the mapped flood hazard areas that are designed to prevent new development from increasing the flood threat and to protect new and existing buildings from anticipated flood events.
3. Hazard identification and mapping under which engineering studies are conducted and flood maps are prepared to delineate areas that are predicted to be subject to flooding under certain conditions.

Federal flood insurance is designed to provide an alternative to disaster assistance and disaster loans for home and business owners. Disaster assistance rarely comes close to covering all of the costs to repair and cleanup. While available to qualified victims, disaster loans do not significantly ease the financial burden due to repayment terms. It is important to remember that disaster assistance is available only after floods have been declared major disasters by the President of the United States. In contrast, insurance claims will be paid any time damage from a qualifying flood event occurs.

The NFIP is intended to encourage States and local governments to recognize and incorporate flood hazards in land use and development decisions. In some communities, this is achieved by guiding development to areas with lower risk. When decisions result in development within floodplains, application of the criteria set forth in 44 CFR 59.1 and 60.3 is intended to minimize exposure and flood-related damage. These are the minimum requirements that a community must adopt in order to participate in the NFIP. In general, the NFIP minimum floodplain management regulations require that new residential structures or substantially improved or substantially damaged existing residential buildings in A zones must have their lowest floor (including basement) elevated to or above the BFE. Non-residential structures in A zones can be either elevated or dry-floodproofed to the BFE. In V zones, the building must be elevated on piles and columns such that the bottom of the lowest horizontal structural member of the

lowest floor of all new construction or substantially improved existing buildings must be elevated to or above the BFE.

Any community may exceed the minimum NFIP requirements by adopting more restrictive regulations. Communities often do this when they have access to information or knowledge of conditions that require, particularly for human safety, higher standards than the minimum NIFP requirements. Therefore, any floodplain management regulations that are more restrictive than the NFIP requirements shall take precedence.

By encouraging communities to guide development to lower risk areas, and by requiring the elevation of new construction and existing buildings that have been substantially improved or substantially damaged, one of the long-term objectives of the NFIP can be achieved: reducing flood damage and losses.

In addition to providing flood insurance and reducing flood damages through floodplain management regulations, the NFIP identifies and maps the nation's floodplains. Mapping flood hazards creates a broad-based awareness of the flood hazards and provides the data needed for floodplain management programs and to actuarially rate new construction for flood insurance.

3.2 Identifying and Mapping Flood Hazards

FEMA is required by statute to identify and map the nation's flood-prone areas and to establish flood-risk zones in these areas. Since the inception of the NFIP, FEMA has complied with this statutory requirement by performing engineering studies of flood-prone communities and producing flood maps. The flood maps are used by mortgage lenders, insurers, real estate agents, map determination companies, community officials, land developers, engineers and surveyors, State and local emergency response officials, and property owners. The flood maps are also used by States and communities for emergency management, land use planning, and water resources planning and by Federal agencies implementing Executive Order 11988, Floodplain Management for Federal actions proposed in or affecting floodplains.

The NFIP would not be able to offer insurance at affordable rates without the existence of risk management (floodplain management) to reduce flood losses. To assess and manage the flood risk, a national standard was needed. The 1-percent annual chance flood was chosen on the basis that it provides a higher level of protection while not imposing overly stringent requirements or the burden of excessive costs on property owners. The 1-percent annual chance flood (or 100-year flood) represents a magnitude and frequency that has a statistical probability of being equaled or exceeded in any given year or, stated alternatively, the 100-year flood has a 26 percent (or 1 in 4) chance of occurring over the life of a 30-year mortgage.

FEMA performs a Flood Insurance Study (FIS) and creates FIRMs delineating the extent of the flood that has a 1-percent chance of being equaled or exceeded in any given year. The delineated area is designated an SFHA, which is the area in which development must be regulated by NFIP floodplain management regulations. Under the NFIP, a floodplain is defined as any land area susceptible to being inundated by floodwaters from any source.

When producing a new FIS and FIRMs or updating existing ones, FEMA typically uses a combination of the two study approaches (approximate and detailed) in identifying a community's flood hazards. Detailed study methods typically employ the use of engineering models and, at a minimum, result in the determination of BFEs or flood depths and floodways that will be displayed on the flood map. Approximate study methods are used to identify flood hazards, but they use more simplified engineering methods to determine the floodplain boundaries; however, BFEs and floodways are not identified or mapped.

In general, the decision on whether to use approximate or detailed study methods is based on existing and anticipated development in and near the floodplain in the community. Flood hazard information for flooding sources that affect developed or developing areas are based on detailed studies whenever possible; approximate study methods generally are used for undeveloped or sparsely developed areas.

When a new or updated detailed FIS is performed, the following information is usually generated:

- BFEs are presented as either water-surface elevations or average depths of flow above the ground surface. These elevations and depths were historically referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). However, as a result of advances in technology, an updated vertical datum – the North American Vertical Datum of 1988 (NAVD 88) – was created and has been officially adopted by the Federal Government as a new basis for measuring heights. Newly updated maps and BFEs are now generally referenced to NAVD 88.
- Water-surface elevations for the 10-year (10-percent annual chance), 50-year (2-percent annual chance), 100-year (1-percent annual chance), and 500-year (0.2-percent annual chance) floods.
- Boundaries of the regulatory floodway. The regulatory floodway is defined as the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the entire base flood (1-percent annual chance flood) discharge can be conveyed with no greater than a 1.0-foot increase in the BFE.
- Boundaries of the 1- and 0.2-percent annual chance floodplains. The 1-percent annual chance floodplain is referred to as the SFHA. The 0.2-percent annual chance flood is the flood that has a 0.2 percent chance of being equaled or exceeded in any given year and is also known as the 500-year flood.

The results of the FIS are presented on the FIRM. An example of a FIRM showing the map and title box is shown in Figure 5-1. FIRMs are now being prepared as a digital product, known as a Digital Flood Insurance Rate Map (DFIRM), which may involve converting an existing manually produced FIRM to digital format, or creating a product from new digital data sources using a Geographic Information System (GIS) environment. A sample DFIRM is shown in Figure 3-1.

Figure 3-1. Sample DFIRM.

The results of the FIS are also presented in a report that accompanies the FIRMs or DFIRMs. The FIS report contains a narrative that describes the flooding conditions in the community, and the types of studies that were performed. The report also contains tables and Flood Profiles. For determining a BFE at a building site, communities should use the Flood Profiles rather than the BFE on the FIRM. A sample FIS summary of discharges is shown in Figure 3-2(a), a sample FIS floodway data table is shown in Figure 3-2(b), and a sample FIS flood profile is shown in Figure 3-2(c). Refer to Section 5.1 for additional details on obtaining FIRM and FIS data. The NFIP FISs and FIRMs can be viewed and ordered online at http://store.msc.fema.gov.

Flood risk zones are shown on the FIRM or DFIRM for the 1-percent annual chance flood as Zone A, Zone A1-30 (on older FIRMs), Zone AE, Zone AO, Zone AH, Zone AR, Zone A99, Zone AR/A, Zone AR/AE, Zone AR/A1-30 (on older FIRMs), Zone AR/AH, Zone AR/AO, Zone V, Zone V1-30 (on older FIRMs), or Zone VE. Table 3-1 provides a general description of the most common flood zone designations for riverine flood areas and inland flood zones in coastal areas. Table 3-2 provides a general description of the most common flood zone designations for coastal flood areas. The zone designations presented on the FIRM or DFIRM depend on the type of flood hazard and type of study performed. The 0.2-percent annual chance floodplain is labeled as Zone B (on older FIRMs) or Zone X (shaded). Areas outside of the SFHA are labeled as Zone C or Zone X (unshaded). Definitions and descriptions of the flood insurance risk zones can be found at: http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/flood_zones.shtm.

Table 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
TENMILE RIVER					
At the downstream corporate limits	210.0	7,500	13,660	16,850	26,280
At South Dover Bridge	194.5	6,930	12,410	15,260	23,470
Downstream from the confluence of the Swamp River	189.0	6,730	11,970	14,710	22,500
Upstream from the confluence of the Swamp River	141.0	4,980	8,300	10,070	14,590
At the upstream corporate limits	130.0	4,580	7,490	9,060	12,940
WELLS BROOK					
At its confluence with the Tenmile River	6.1	610	1,010	1,270	1,960
At a point approximately 0.8 mile upstream of its confluence with the Tenmile River	2.6	430	750	930	1,380

Figure 3-2(a). Sample FIS Summary of Discharges table.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE (FEET NGVD)
Tenmile River (continued)								
x	49,320[1]	260	1,992	4.8	374.3			
Y	52,410[1]	120	1,035	9.2	377.2			
Z	54,310[1]	250	1,746	5.5	382.4			
AA	57,590[1]	275	1,664	5.8	387.9			
AB	58,470[1]	301	2,386	4.0	390.2			
Wells Brook								
A	725[2]	115	270	4.1	375.6			
B	1,980[2]	28	168	6.6	380.2			
C	4,280[2]	69	270	4.1	391.3			

[1]Feet above corporate limits
[2]Feet above concluence with Tenmile River
[3]Elevation computed without consideration of backwater effects from Tenmile River

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY
TOWN OF DOVER, NY
(DUTCHESS CO.)

FLOODWAY DATA
TENMILE RIVER AND WELLS BROOK

Figure 3-2(b). Sample FIS Floodway Data.

Figure 3-2(c). Sample FIS Flood Profile.

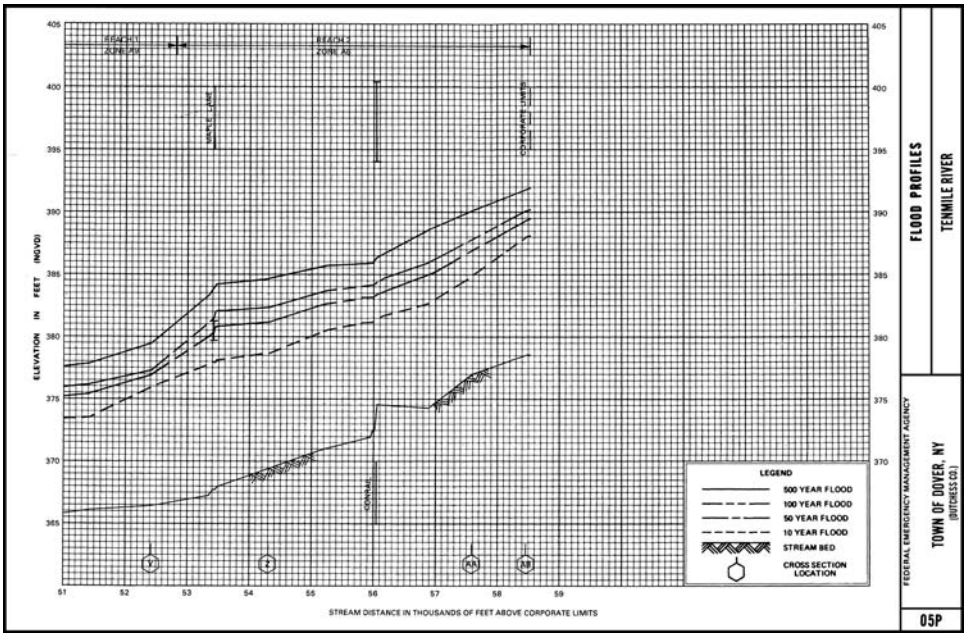


Table 3-1. Common SFHA Designations for Riverine or Inland Flood Zones

Zone	Description
Flood Risk Zones	
A	>ob^p pr_gb`q q l fkrka^qflk _v qeb .*mbo`bkq ^kkr^i `e^k`b «l l a bsbkq+ ?b`^rpb abq^fiba hydraulic analyses are not used, no BFE or depths are shown.
AE and A1-30[1]	>ob^p pr_gb`q q l fkrka^qflk _v qeb .*mbo`bkq ^kkr^i `e^k`b «l l a bsbkq abqbo j fkba _v detailed methods. BFEs are shown.
AH and AO	>ob^p pr_gb`q q l fkrka^qflk col j qeb .*mbo`bkq ^kkr^i `e^k`b «l l a qe^q e^sb «l l a abmqep lc _bq t bbk . ^ka 0 cbbq+ >L wlkbp `^k _b bfqebo mlkafkd ^ob^p lo pebbq «l t ^ka ^ob ^ppfdkba ^ _^pb «l l a abmqe j b^proba fk cbbq ^_lsb qeb dolrka+ >E wlkbp ^ob generally ponding areas and are assigned a BFE.

[1] Zone designations found on older FIRMS have been replaced by the designation listed in the same box above them.

Table 3-2. Common SFHA Designations for Coastal Flood Areas

Zone	Description
Flood Risk Zones	
V	>ob^p pr_gb`q q l fkrka^qflk col j qeb .*mbo`bkq ^kkr^i `e^k`b «l l a fk `l^pq^i ^ob^p t ebob qebob fp ^ sbil`fqv e^w^oa arb ql t^sb ^`qflk ^ka) _v ab^kfqflk) qeb bkqfob Primary Frontal Dune. No BFEs have been determined.
VE V1-30[1]	>ob^p pr_gb`q q l fkrka^qflk col j qeb .*mbo`bkq ^kkr^i `e^k`b «l l a fk `l^pq^i ^ob^p where there is a velocity hazard due to wave action. BFEs have been determined and are shown on the FIRM.

[1] Zone designations found on older FIRMs have been replaced by the designation listed in the same box above them.

In addition to the SFHAs labeled as V zones, there are some A zones, generally located landward of and contiguous to V zones, where flooding characteristics may include wave action, high velocity flows, and erosion or scour. These are referred to as Coastal A zones, and they are further described below and in Section 3.7.

Along rivers, streams, and lakes within the U.S., FEMA computes BFEs using computer models, statistical techniques, or both. These elevations are a function of the amount of water expected to enter a particular system by means of precipitation and runoff. The SFHAs along rivers, streams, and lakes are labeled as A zones.

Along the coast, FEMA determines SFHAs by an analysis of storm surge, wind direction, wind speed, wave heights, and other factors. FEMA designates these areas along the coast as both V and A zones on the FIRM or DFIRM.

FEMA applies the VE zone designation to those areas along the coast where water depth and other conditions would support at least a 3-foot wave height. FEMA also considers other factors in identifying VE zones, such as wave runup and the existence of a Primary Frontal Dune. FEMA usually designates AE zones in coastal areas landward of the VE zone. Coastal flood hazard areas mapped as AE zones can be subject to storm surge and damaging waves; however, the waves are less than 3 feet in height.

Currently, NFIP regulations make no distinction between the design and construction requirements for coastal AE zones and riverine AE zones. However, evidence suggests that design and construction requirements in some portions of coastal AE zones should be more like VE zone requirements. One of the hazard identification criteria for VE zone designation is where wave heights are estimated to be equal to or greater than 3 feet. Unfortunately, post-storm investigations have shown that typical AE zone construction techniques (e.g., wood frame, light gauge steel, or masonry walls on shallow footings or slabs, etc.) are subject to damage when exposed to waves less than 3 feet in height. Laboratory tests and post-disaster field investigations confirm that wave heights as small as 1.5 feet can cause failure of the above-listed wall types. Other flood hazards associated with coastal waves (e.g., floating debris, high velocity flow, erosion, and scour) also damage AE zone-type construction in these coastal areas.

As a result, for all new detailed coastal studies starting in 2009, FEMA will delineate the landward limit of waves 1.5 feet in height on the FIRMs and include this information in the DFIRM database as an informational layer. The landward limit of the area affected by waves greater than 1.5 feet is called the Limit of Moderate Wave Action (LiMWA). The LiMWA will be included on the preliminary FIRM; however, if a community does not want to delineate the limit on its final FIRMs, the community may provide a written request to FEMA with justification for such a request. There are no NFIP floodplain management requirements that communities must adopt or special insurance ratings associated with the designation of the LiMWA. However, communities are encouraged to adopt higher standards than the minimum NFIP requirements in these areas to address the increased risks associated with waves and velocity action.

3.3 The NFIP's Community Rating System (CRS)

The NFIP's Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.

As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS:

1. Reduce flood losses
2. Facilitate accurate insurance rating
3. Promote the awareness of flood insurance

For CRS participating communities, flood insurance premium rates are discounted in increments of 5 percent; a Class 1 community would receive a 45 percent premium discount, while a Class 9 community would receive a 5 percent discount (a Class 10 is not participating in the CRS and receives no discount). The CRS classes for local communities are based on 18 creditable activities, organized under four categories:

1. Public Information
2. Mapping and Regulations
3. Flood Damage Reduction
4. Flood Preparedness

3.4 NFIP Definitions Related to Manufactured Homes

In addressing the NFIP floodplain management requirements for manufactured homes, it is useful to define key terms. The following definitions are found in the NFIP floodplain management regulations at 44 CFR 59.1 unless noted otherwise. Several NFIP definitions can also be found in Appendix D. The definition for “manufactured home” does not include a recreational vehicle.

- "Manufactured home” means a structure, transportable in one or more sections built on a chassis and designed for use with/without a permanent foundation when attached to utilities.
- “Manufactured home park or subdivision” means a parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.
- “Existing manufactured home park or subdivision” means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be

Permanent Foundations

A permanent foundation is a foundation constructed of durable materials that may include masonry, reinforced concrete, corrosion resistant steel, or pressure treated timber. The foundation designs provided in Appendix H are considered permanent founda- qfl kp fk ^``loa^k`b tfqe qefp ab^{a}k* ition.

affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by the community.

- "New manufactured home park or subdivision" means a manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of the floodplain management regulations adopted by a community.
- "Expansion to an existing manufactured home park or subdivision" means the preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).
- "Substantial damage" means damage of any origin sustained by a structure whereby the cost of restoring the structure to the condition before damage would equal or exceed 50 percent of the market value of the structure before the damage occurred.
- "Substantial improvement" means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed. The term does not, however, include either (1) any project for improvement of a structure to correct existing violations of State or local health, sanitary, or safety code specifications that have been identified by the local code enforcement official and that are the minimum necessary to ensure safe living conditions, or (2) any alteration of a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."

3.5 General NFIP Floodplain Management Requirements for Manufactured Homes

Under the NFIP, participating communities are required to regulate all development in SFHAs. "Development" is defined in the NFIP regulations as:

> "Any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials." [44 CFR 59.1]

Before a property owner can undertake any development in the SFHA, a permit must be obtained from the community. The community is responsible for reviewing all permit applications to determine whether development complies with the community's floodplain management regulations. Communities are also required to review proposed development in SFHAs to

ensure that all necessary permits have been received from those government agencies from which approval is required by Federal or State law, such as 404 wetland permits from the U.S. Army Corps of Engineers (USACE) or permits under the Endangered Species Act.

The NFIP requires manufactured homes to meet the same basic regulatory requirements that are required for residential structures in the floodplain. The following general NFIP minimum standard applies to all residential structures in the floodplain in which communities are to:

> "Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding." [44 CFR 60.3(a)]

The NFIP also requires that new manufactured home parks and subdivisions meet the same basic requirements as all other subdivision proposals in which communities are to:

> "Review subdivision proposals and other proposed new development, including manufactured home parks or subdivisions, to determine whether such proposal will be reasonably safe from flooding. If a subdivision proposal or other proposed development is in a flood-prone area, any such proposals shall be reviewed to assure that:
>
> (i) all such proposals are consistent with the need to minimize flood damages within the flood-prone area,
>
> (ii) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located and constructed to minimize or eliminate flood damage, and
>
> (iii) adequate drainage is provided to reduce exposure to flood hazards." [44 CFR 60.3(a)(4)]

3.6 NFIP Requirements for Manufactured Homes in Riverine and Inland Flood Zones

Generally, manufactured homes must meet the same flood protection requirements as a "stick built" or typical housing. The general requirement for manufactured homes like typically built residential structures is that they must be elevated so that the lowest floor is above the BFE. This applies to new or substantially improved or substantially damaged manufactured homes.

BFE and DFE

?^pb «l la bibs^qflk %?CB& – The water surface elevation resulting from the base, or 100-year (1 per- `bkq ^kkr^i `e^k`b& «l la+

Abpfdk «l la bibs^qflk %ACB& ¬ Qeb bibs^qflk ql tef`e absbilm j bkq fk qeb obdri^qlov «llami^fk fp built. At a minimum, the DFE is equivalent to the BFE. However, in some areas, the DFE includes an additional freeboard height above the BFE as shown in the formula below.

DFE = BFE + Freeboard

Freeboard – An additional elevation requirement some height (1, 2, or more feet) above the BFE that provides a margin of safety above the estimated BFE.

As indicated above, the minimum DFE requirement for NFIP communities is the BFE. However, in communities where a higher degree of protection is promoted or required, the DFE includes a freeboard height above the BFE. This freeboard provides a margin of safety above the estimated BFE and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties. The NFIP encourages participating communities to adopt and enforce freeboard obnrfob j bkqp ^p m^oq lc qebfo il `^i «llami^fk j ^k^db j bkq loafk^k`b+Qefp fp pel tk fk 11 @CO 3-+.%a&8 tef`e pq^qbp) ¦>kv «llami^fk j ^k^db j bkq obdri^qflkp ^almqba _v ^ Pq^qb lo ^ `l j jrkfqv tef`e ^ob more restrictive than the criteria set forth in this part are encouraged and shall take precedence."

3.6.1 Approximate A Zones

Approximate A zones are not studied using detailed methods; therefore, BFEs have not been developed. When a manufactured home is proposed on an approximate A zone site, the community must make every effort to obtain any BFE data and floodway data in order to achieve a reasonable measure of flood protection.

> "Obtain, review, and reasonably utilize any base flood elevation and floodway data available from a Federal, State, or other source…."[44 CFF 60.3(b)(4)]

BFE data may be available from a variety of sources such as local hydrologic and hydraulic (H&H) studies, State Departments of Natural Resources, or from Federal agencies such as the USACE. Several other sources of BFE data are identified in FEMA 265, *Managing Floodplain Development in Approximate Zone A Areas, A Guide for Obtaining and Developing Base (100-year) Flood Elevations.*

If BFE or floodway data cannot be obtained from these sources, the community should consider conducting, or requiring the applicant to conduct, a site-specific engineering analysis to determine a BFE. Guidance for developing a BFE is available in FEMA 265.

If no BFE data are available, communities must ensure that building sites will be reasonably safe from flooding for proposed developments. A simplified method for estimating a BFE as well as other methods for ensuring a building site is reasonably safe from flooding can also be found in FEMA 265.

When a new manufactured home park or subdivision is being planned on a site that is greater than 50 lots or 5 acres (whichever is less), BFE data must be developed for approximate A zones through the use of detailed study methodologies similar to those used in creating the FIS. Under this requirement, the community must:

> "Require that all new subdivision proposals and other proposed development (including proposals for manufactured home parks and subdivisions) greater than 50 lots or 5 acres, whichever is the lesser, include within such proposals base flood elevation data." [44 CFR 60.3(b)(3)]

The community can perform a study to determine these elevations or require the developer to fund or complete the study. When the 50-lot, 5-acre threshold is surpassed and the development includes one or more lots that lie at least partially within the floodplain, BFE data must be developed through detailed study methodologies. If the developer completes the study, it is subject to approval by the community.

For manufactured home sites that are below the 50-lot/5-acre threshold and BFE data for those sites are not available from other sources, communities should consider conducting or requiring the permit applicant to develop a BFE in an approximate A zone. In addition to reducing flood damages, there are other advantages of developing a BFE. For example, flood insurance policies obtained in approximate A zones that are rated using a BFE developed using a detailed study methodology will often qualify for significantly lower insurance rates than policies that are rated without a BFE. The difference in flood insurance premiums could be substantial.

If a manufactured home is proposed in an approximate A zone where BFE data are not available from a Federal, State, or other source, the community must require that:

> "…all manufactured homes to be placed within Zone A on a community FHBM or FIRM shall be installed using methods and practices which minimize flood damage. For the purpose of this requirement, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include, but are not limited to, the use of over-the-top frame ties to ground anchors. This requirement is in addition to applicable State and local anchoring requirements for resisting wind forces." [44 CFR 60.3(b)(8)]

This minimum standard requires that manufactured homes be elevated and anchored to resist flood and wind forces. If elevation data are not available from a Federal, State, or other source, FEMA advises communities to require manufactured homes under this provision to be elevated at a minimum of 3 feet or higher from the highest adjacent grade to minimize flood damages. Guidance for anchoring is further addressed in Section 3.6.5 and in Chapter 7. The areas below the 3-foot elevation must be constructed with flood-resistant materials and utilities, and mechanical equipment must be elevated to the 3-foot elevation. Any utility and mechanical components that must be below the BFE must be made watertight to the 3-foot elevation as described in 3.6.7.

When BFEs or floodway data are obtained for manufactured home sites, the manufactured home must meet the elevation and floodway standards described in Sections 3.6.2 and 3.6.9.

3.6.2 Elevation in A, A1-30, AE, and AH Zones

Most manufactured home placements are subject to the same performance standards as typically built residential structures. The performance standard for the placement of these manufactured homes is addressed in this section. An exception has been made for the placement of manufactured homes in existing manufactured home parks or subdivisions which is addressed in Section 3.6.3.

The NFIP requires that manufactured homes placed or substantially improved in Zones A1-30, AH, or AE on the community's FIRM on sites:

> (i) "Outside of a manufactured home park or subdivision,
>
> (ii) In a new manufactured home park or subdivision,
>
> (iii) In an expansion to an existing manufactured home park or subdivision, or
>
> (iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood,
>
> be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement." [44 CFR 60.3(c)(6)]

This requirement establishes the basic elevation and anchoring standards that apply to most manufactured home placements, including those outside of manufactured home parks and subdivisions and in new manufactured home parks and subdivisions. These manufactured homes must have their lowest floors elevated to or above the BFE. These requirements also apply to manufactured homes placed in expansions to existing manufactured home parks and on lots where manufactured homes are substantially damaged by flood. Once a manufactured home in an existing manufactured home park or subdivision is substantially damaged by flood, from that point on all manufactured homes placed on that lot must be elevated to or above the BFE.

The best way to meet the elevation requirement described above is to elevate the bottom of the manufactured home steel frame to the BFE. The manufactured home must be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement. Section 3.6.5 and Chapter 7 address anchoring in more detail.

This guide recommends for A zones the best practice of placing the bottom of the manufactured home's steel frame at the BFE and not the il tbpq «llo lc qeb j^krc^`qroba el j b fk loabo ql mobsbkq «lla a^j-^db ql qeb «llo ^ka lqebo fkqbofllo ^kfpebp ^ka `lkqbkqp %Cfdrob 0*O&+

As with stick built housing, all parts of the manufactured home below the BFE must be constructed with

flood damage-resistant materials and utility systems must either be elevated or made watertight to the BFE.

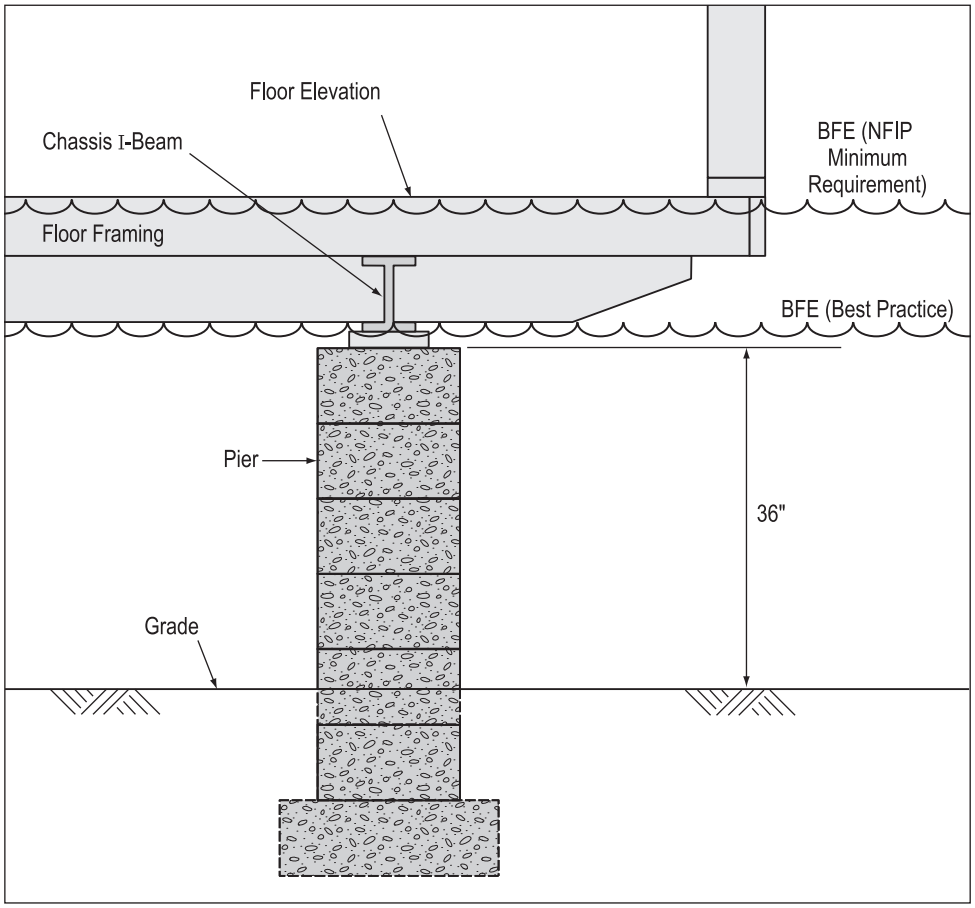


Figure 3-3. Manufactured home with lowest floor elevated to the BFE.

3.6.3 3-Foot Pier Foundation

The NFIP allows for a limited exemption to elevating to the BFE by allowing elevating to no less than 36 inches in height above grade for lots in existing manufactured home parks in Zones A1-30, AE, or AH on the community's FIRM. A manufactured home placed in an existing manufactured home park must meet either of the following requirements:

> "(1) The lowest floor of the manufactured home is at or above the base flood elevation; or
>
> (2) The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement." 44 CFR 60.3(c)(12).

The elevation requirements above apply in existing manufactured home parks or subdivisions established before the date of the community's initial floodplain management regulations when:

1) A manufactured home is being placed or replaced with a new model in an existing community or subdivision, or

2) A manufactured home is being replaced in an existing manufactured home park or subdivision when the previous home had sustained substantial damage due to reasons other than a flood.

The selection of the 36-inch pier foundation does not apply to the repair or replacement of a manufactured home on a site in an existing manufactured home park where a manufactured home has been substantially damaged by flood.

The option of allowing elevating 36 inches in height above grade is a compromise to balance the flood hazard against the economic impacts on some manufactured park owners that would result if elevation to the BFE were required. There are often practical difficulties in elevating manufactured homes to the BFE in many older parks due to small lot sizes and the split ownership of the manufactured home and the lot itself.

3-Foot Pier Foundation

The 3-foot pier foundation is one option for manufactured homes installation in existing manufactured home parks or subdivisions. However, the NFIP strongly encourages elevating to the level of the BFE or higher for increased safety and property protection and reduced flood insurance premiums.

It is important to note that, when the 36-inch pier foundation is selected, the manufactured home may not be protected to the level of the BFE. For this reason, care must be exercised in using the 36-inch pier foundation option. This option may not be appropriate in communities where the flood hazard may be so severe, such as deep floodplains and high velocity areas, that it would place lives and property at too great a risk. Some communities may find placement of a manufactured home in an existing manufactured home park can accommodate elevation to the BFE.

If the option of elevating the manufactured home to 36 inches above grade is chosen, the strength of the anchoring system must be increased in order to resist the additional flood forces that will be exerted upon the foundation since it is possible that water will reach or exceed the level of the home's floor. Therefore, under this scenario, the use of typical manufactured home installation methods such as foundations using dry-stack blocks and ground anchors would preclude the use of the other foundation designs in this guide.

No matter which option is chosen for elevating a manufactured home in an existing manufactured home park, the manufactured home must be securely anchored to an adequately anchored foundation system to resist flotation, collapse, or lateral movement.

As with stick built housing, all parts of the manufactured home below the BFE must be constructed with flood-resistant materials and utility systems must either be elevated or made watertight to the BFE. The best way to meet the requirement for flood resistance is to elevate the bottom of the manufactured home steel frame to the BFE.

Figure 3-4 shows a typical example of a foundation used on manufactured housing per the 36-inch pier foundation alternative. The pier, footing, and connection between the pier and the home must be designed to resist flotation, collapse, or lateral movement.

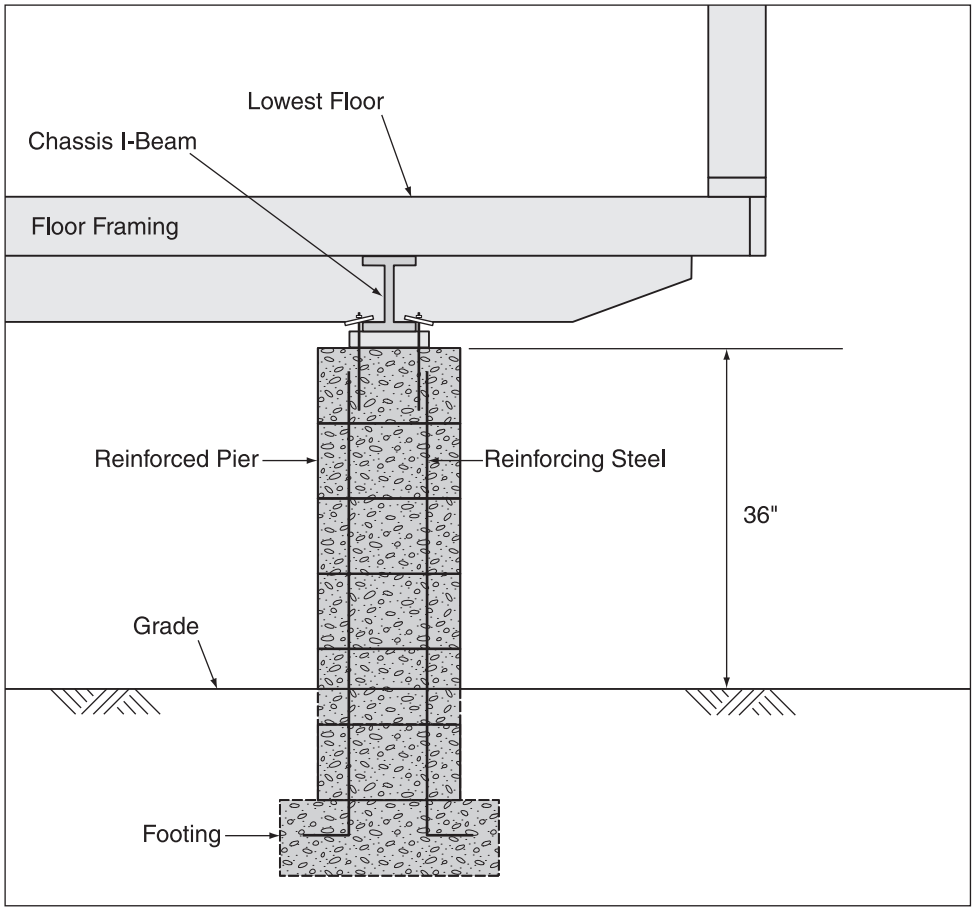


Figure 3-4. Manufactured home on reinforced pier foundation 36 inches high.

3.6.4 Elevation in Zone AO

A Zone AO is an area of shallow flooding with flood depths between 1 and 3 feet with no clearly defined channel. FIRMs indicate a flood height above grade that is based on an average depth to which structures must be raised for Zone AO.

Manufactured homes placed or substantially improved in Zone AO must meet the same standards as other residential structures and have their lowest floor elevated above the highest adjacent grade at least as high as the depth number specified on the FIRM.

HUD manufactured home standard 24 CFR 3285.305 requires a minimum clearance of 12 inches between the lowest member of the main frame and the ground surface, and the manufactured home main frame is typically 0.5 feet to 1 feet deep; therefore, the lowest floor level is typically 1.5 to 2 feet above grade. Under this scenario, meeting the NFIP elevation requirement for Zone AO may already be met or require a relatively small additional elevation of up to 1.5 feet. This additional elevation can be accomplished using installation techniques found in this guide, such as placing the home on piers and securing it with ground anchors.

Standard installation techniques provide a foundation that is typically elevated at least 3 feet above grade, and flood depths in Zone AO are typically 3 feet or less. Therefore, the placement or substantial improvement of manufactured homes in Zone AO are typically elevated to or above the base flood level, even if they are being placed in an existing manufactured home park or subdivision. However, the recommended best practice is to elevate the bottom of the steel frame to the BFE in Zone AO.

As in the other A zones, manufactured homes in Zone AO must be anchored to resist flotation, collapse, or lateral movement. The areas below the Zone AO flood depth must be made with flood damage-resistant materials, and utilities and mechanical equipment must be elevated to the flood depth specified on the FIRM. Any utility and mechanical components that must be below the BFE must be made watertight to the Zone AO flood depth. Refer to Sections 3.6.6 and 3.6.7 and Chapter 7 for additional details on these requirements.

3.6.5 Anchoring

In addition to the elevation requirement, manufactured homes are required to be securely attached to an adequately anchored foundation system to resist flotation, collapse, or lateral movement:

> "[Manufactured homes must] …and be securely anchored to an adequately anchored foundation to resist flotation, collapse and lateral movement." [44 CFR 60.3(c)(6) and (c)(12)]

"Adequately anchored" is considered to be a system of ties, anchors, and anchoring equipment that will withstand flood and wind forces.

Anchor and Tie-down Systems

Anchor and tie-down systems must meet load requirements stipulated in locally adopted installation ordinances. Many communities across the country have adopted or are in the process of adopting the International Code Council's (ICC's) model building codes, which include the International Residential Code® of 2009 (IRC® 2009). IRC 2009 stipulates working load requirements of 3,150 pounds with a 50 percent overload or 4,725 pounds for manufactured home anchoring systems.

Florida's manufactured home installation requirements, *Rules of Department of Highway Safety and Motor Vehicles Division of Motor Vehicles, Chapter 15C-1*, for homes manufactured before July 14, 1994, have the same loading standards for anchor systems as those found in the IRC 2009, a working load of 3,150 pounds with an ultimate load of 4,725 pounds. However, for homes manufactured after July 14, 1994, the system must be able to resist a working load of 4,000 pounds with an ultimate load of 6,000 pounds.

Additional guidance on anchoring manufactured homes can be found in Chapter 7.

3.6.6 Flood Damage-Resistant Materials

When a manufactured home is elevated, it is important that all parts exposed to floodwaters be made of flood damage-resistant materials. This includes all portions of the manufactured home such as foundation elements and any enclosures below the BFE.

> "[Community must] Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a floodprone area, all new construction and substantial improvements shall...(ii) be constructed with materials resistant to flood damage..." [44 CFR 60.3(a)(3)]

"Flood [damage]-resistant material" is described in FEMA Technical Bulletin 2 as "any building product [material, component or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage." The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than cosmetic repair. "Cosmetic repair" includes cleaning, sanitizing, and resurfacing (e.g., sanding, repair of joints, repainting) of the material.

For further information on flood-resistant materials refer to FEMA Technical Bulletin 2, *Flood Damage-Resistant Material Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program.*

3.6.7 Utilities and Mechanical Equipment

The manufactured home's utilities and mechanical equipment need to be protected. Their location below the BFE can make them susceptible to being inundated by floodwaters and damaged by floating debris. Utilities and mechanical equipment must:

> "…be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding." [44 CFR 60.3(a)(3)(iii)]

Essentially, utility systems and mechanical equipment must be elevated to or above the BFE. Elevating utilities and mechanical equipment such as furnaces, hot water heaters, and heating, ventilation, and air conditioning equipment (HVAC) is the best protection. With most outdoor HVAC compressors, the main issues presented by floodwaters are inundation, velocity flow, and debris impact. The control and power circuits and mechanical parts in HVAC equipment, even when they are designed for outdoor installations, are not designed to withstand inundation by floodwaters. The most effective flood-resistant design for outdoor HVAC compressors is to strap or bolt the equipment onto a platform above the BFE.

Utility and mechanical components that must be below the BFE must be made watertight to the BFE. Examples of this include sealing on-site water well casings to prevent water intrusion or enclosing HVAC equipment in a flood-resistant enclosure so that it is protected to the BFE.

The NFIP does not recommend locating ductwork below the BFE for manufactured homes located in SFHAs. There is no known or cost-effective technique for designing air ducts to keep floodwaters from entering or accumulating within the systems components during inundation by floodwaters. If ductwork must be installed below the BFE, it should be minimized as much as possible. Placing the bottom of the steel frame at the BFE as recommended enhances protection of utility and mechanical equipment. The exception would be installation of cross-over duct work for manufactured housing that needs to pass under chassis frame members. If cross-over ducts are used, elevating the manufactured home 1 to 2 feet above the BFE will prevent them from being damaged during flood events.

Additional guidance for protecting utility and mechanical systems can be found in FEMA 348, *Protecting Building Utilities From Flood Damage, Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems.*

3.6.8 Enclosed Areas

Generally, the space beneath the lowest floor of manufactured home is covered by some type of skirting or screening. Manufactured homes are also often installed on an enclosed foundation (see Chapter 8) when the BFE is several feet above grade.

When an enclosed area below the lowest floor of a manufactured home is created, special attention is needed for two reasons:

- The walls of enclosed areas are subject to flood damage from hydrostatic and hydrodynamic forces.
- People are tempted to convert enclosures that are intended to flood into areas that can sustain damage in a flood.

To protect enclosed areas below the lowest floor, the community must:

> "Require, for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters." [44 CFR 60.3(c)(5)]

The NFIP allows only certain uses of the enclosed area below the lowest floor of an elevated manufactured home. These spaces can only be used for parking of vehicles, building access, or storage.

Additionally, the enclosure must be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. To protect the enclosure, the NFIP minimum requirements are:

- A minimum of two openings in walls of the enclosure having a total net area of not less than 1 square inch for every square foot of enclosed area subject to flooding.
- The bottom of all openings must not be higher than 1.0 foot above the higher of the exterior or interior grade or floor immediately below the opening.
- Openings must permit the automatic entry and exit of floodwaters. The openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they meet this requirement.
- Alternative designs are allowed but must be certified by a registered professional engineer or architect as meeting the requirement to automatically equalize forces on exterior walls by allowing for the entry and exit of floodwaters.

To further minimize flood damages, mechanical, electrical, plumbing equipment, and other service facilities must be designed and/or located so as to prevent damage during conditions of flooding (see Section 3.6.7). Enclosures below the BFE must also be constructed with flood damage-resistant materials.

If the area below the manufactured home is enclosed with rigid skirting that is less likely to be dislodged by wind or flood loads, openings are required to equalize hydrostatic pressure in accordance with NFIP regulations.

For further information on enclosed areas refer to FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program.*

3.6.9 Floodways

If a community receives a proposal for the development in the SFHA, the community must ensure that the proposal will not impose flood problems on other properties. To prevent this, communities must adopt floodways to designate those areas where flood flows are most sensitive to changes brought on by development. The NFIP defines the floodway as:

> "….the channel of a river or other watercourse and adjacent land area that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height." [44 CFR 59.1]

A floodway is the central portion of a riverine floodplain needed to carry the deeper, faster moving water. A floodway is included with most riverine Flood Insurance Studies and will generally

be shown on the FIRM or DFIRM as indicated in Figure 3-5. A floodway schematic is provided in Section 4.4.1.1 (Figure 4-2). The area chosen for the regulatory floodway must be designed to carry the waters of the 1-percent annual chance flood without increasing the water surface elevation of that flood more than 1 foot at any point.

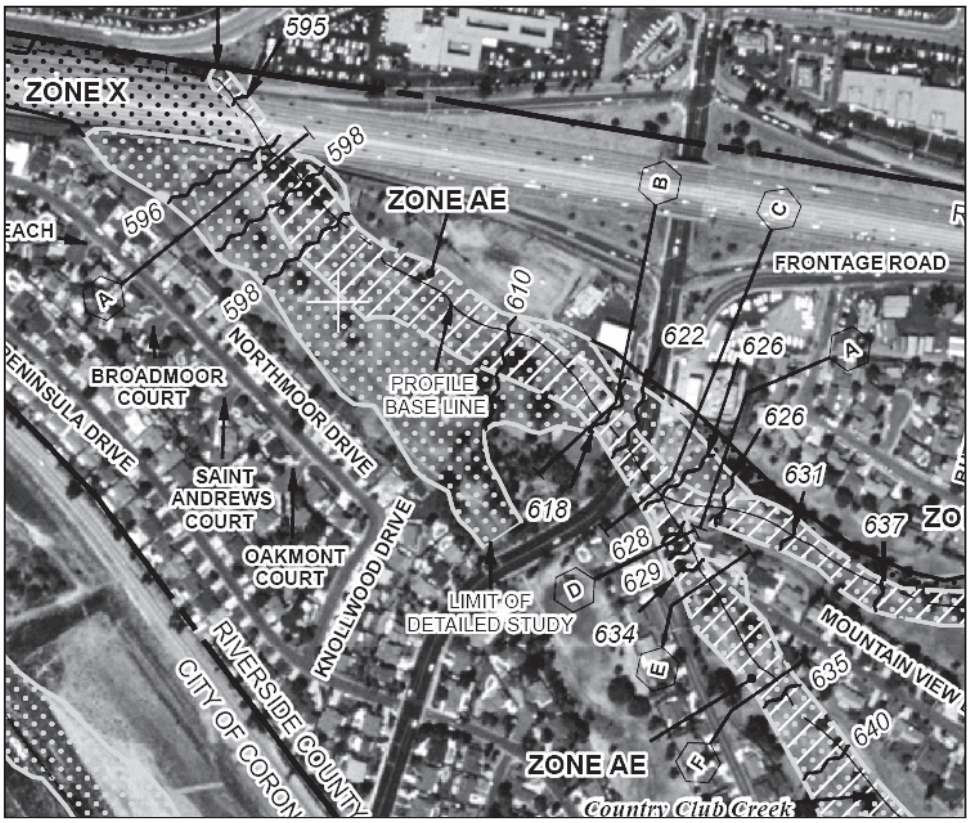


Figure 3-5. DFIRM showing the floodway (cross-hatched area in Zone AE).

Once a community has adopted a floodway, it must prohibit development in the floodway unless it has been demonstrated through H&H analyses performed using standard engineering practice that the development will not result in any increase in flood levels during the base flood. This "encroachment analysis" is required under the following NFIP provision:

> "Prohibit encroachments in the floodway, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during occurrence of the base flood discharge." [44 CFR 60.3(d)(3)]

FEMA defines "any increase" as meaning a zero increase (greater than 0.00 feet). This analysis is usually called a "no-rise" or "zero-rise" analysis and results in a "no-rise" or "zero-rise" certification by a qualified registered professional engineer. Remember that considerable encroachment into the floodplain was already allowed when the floodway was designated by the community. Although some communities or States perform the H&H analyses themselves, most

require the permit applicant to obtain the services of a qualified registered professional engineer to perform the analysis and provide the certification. Generally, very little development or disturbance is permitted in the floodway because even minor encroachments in the floodway lead to increases in the BFE. Unless the engineering analysis demonstrates that there will not be an increase in the BFE as a result of the development, the permit must be denied.

For streams and other watercourses where FEMA has provided BFEs, but no floodway has been designated, the community must review developments on a case-by-case basis to ensure that these increases do not occur, as stated in 44 CFR 60.3(c)(10), in which communities must:

> "Require until a regulatory floodway is designated, that no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1–30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community." [44 CFR 60.3(c)(10)]

3.7 NFIP Requirements for Manufactured Homes in Coastal Flood Areas

Flood hazard areas along coastlines that are subject to flooding from storm surge and wave impacts during coastal storms and hurricanes are designated on the FIRMs as Zones V1-30, VE, and V. In general, different standards than those in riverine floodplains apply in V zones to help manufactured homes withstand wave impacts. Many V zones are also subject to erosion and scour, which can undercut manufactured home foundations.

In addition, some A zones near the coast, generally located landward of and contiguous to V zones, experience V zone flooding characteristics, including wave action, high velocity flows, and erosion or scour. These are referred to as Coastal A zones. While the forces in Coastal A zones are not as severe as those in V zones, they can still cause damage to manufactured housing and foundations.

Although there are no distinct NFIP floodplain management regulations for Coastal A zones, this guide recommends that V zone regulations be followed within Coastal A zones where flood forces are generally stronger and more destructive than those in non-Coastal A zones.

Coastal A Zones

NFIP regulations do not differentiate between Coastal and non-Coastal A zones. However, this guide recommends that manufactured housing in Coastal A zones be installed to be more obpfpq^kq ql «lla clo`bp clrka fk `l^pq^i «lla ^ob^p) fk`irafkd t^sb bccb`qp) sbil`fqv «ltp) bolsion, and scour.

44 CFR 60.3(e) outlines the NFIP requirements for manufactured homes in coastal flood hazard areas in relation to elevation and anchoring, fill, enclosed areas and breakaway walls, and setbacks. Each of these requirements will be addressed in Sections 3.7.1 through 3.7.4, respectively.

In addition to these requirements, manufactured homes in coastal flood areas are required to meet many of the same requirements as manufactured homes constructed in riverine and inland flood areas, such as the use of flood damage-resistant materials below the BFE (Section 3.6.6) and protection of utilities and mechanical equipment (Section 3.6.7).

3.7.1 Elevation and Anchoring

Manufactured homes placed or substantially improved in V zones must be elevated so that the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE in sites:

> "(i) Outside of a manufactured home park or subdivision, (ii) In a new manufactured home park or subdivision, (iii) In an expansion to an existing manufactured home park or subdivision, or (iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood, meet the standards of paragraphs (e)(2) through (e)(7) of 44 CFR 60.3." [44 CFR 60.3(e)(8)]

Elevation requirements for structures in the V zones differ from those in the A zones. In A1-30, AE, A, and AO zones, the finished floor elevation (i.e., top of floor) must be elevated to or above the BFE. Structures in V zones must be elevated so that *"the bottom of the lowest horizontal structural member of the lowest floor is elevated to or above the BFE."* For manufactured homes, the lowest horizontal structural member would generally be the chassis main steel beams. Having the bottom of the lowest horizontal structural member to or above the BFE minimizes flood damages due to wave action. Figure 3-6 illustrates the reference level requirement.

44 CFR 60.3 (e)(4) requires the community to:

> "Provide that all new construction and substantial improvements in Zones V1-30, VE, and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that (i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and (ii) the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design, specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e)(4)(i) and (ii) of this section."

Satisfying 44 CFR 60.3(e)(4)(ii) means that flood and wind loads are to be considered acting simultaneously in the design of elevated portions of the building, its foundation, and its attachment to the structure, so that the building will not be subject to flotation, collapse,

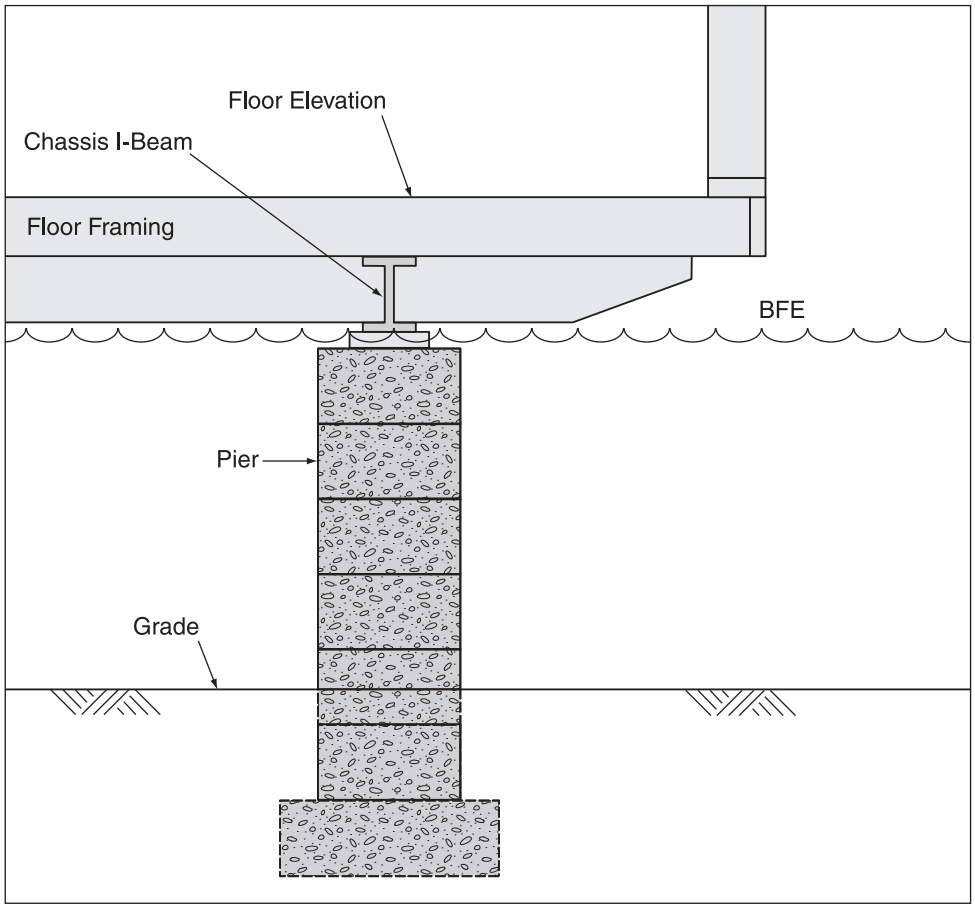


Figure 3-6. Manufactured home with the bottom of the lowest horizontal structural member elevated to the BFE.

displacement, or other structural damage. Design wind loads are to comply with State or local building standards.

Manufactured homes to be placed or substantially improved on sites in an existing manufactured home park or subdivision in V zones must be elevated so that the bottom of the lowest horizontal structural member of the lowest floor is to or above the BFE or meet the 3-foot pier foundation addressed in Section 3.6.3. In the case of the 3-foot foundation, it is important to note that structures in V zones are subject to wave action, intense hydrodynamic pressures, and generally deeper flood depths than riverine areas. Foundations in V zones need to be designed to withstand flood forces from breaking waves and greater flood depths from storm surge. The 3-foot foundation should not be expected to withstand these forces. For these reasons, the NFIP recommends that all manufactured homes in V zones be elevated to or above the BFE. FEMA's *Coastal Construction Manual* (FEMA 55) recommends that the lowest horizontal structural members in coastal areas should be perpendicular to the expected wave crest.

As discussed in Section 3.2, post-storm investigations have indicated that typical AE Zone constructed buildings along the coast are subject to considerable damage when exposed to waves less than 3 feet and as small as 1.5 feet in height. Evidence from these post-storm investigations suggests that design and construction requirements in some portions of Coastal AE zones should be more like the VE zone requirements to minimize damages.

To help communities identify those Coastal AE zone areas subject to damaging wave heights, FEMA will delineate the landward limit of the area affected by waves greater than 1.5 feet in height on the FIRMs and include this information in the DFIRM database as an informational layer. As indicated in Section 3.2, FEMA refers to this limit as the LiMWA. Communities are encouraged but not required to adopt the coastal AE Zone area defined by the LiMWA and adopt and enforce higher building standards than the minimum NFIP requirements in these areas.

Furthermore, the 2009 International Building Code® (IBC®) references the American Society of Civil Engineers (ASCE) 24-05 *Flood Resistant Design and Construction* standard, which has specific design requirements, similar to Zone VE construction, that apply to areas that may be affected by waves greater than 1.5 feet (which ASCE 24 refers to as Coastal A zones). In addition, every FEMA coastal construction publication since the issuance of FEMA 55, *Coastal Construction Manual*, dated June 2000, has recommended the use of Zone VE construction practices in areas subject to wave heights greater than 1.5 feet. The NFIP's CRS provides credits for communities that adopt and enforce more stringent floodplain management requirements in these areas.

3.7.2 Fill

Due to the wave action and more intense hydrodynamic forces experienced in coastal flood areas that lead to erosion and scour, elevating on structural fill is not permitted in V zones. Under the NFIP, the use of fill is prohibited for structural support.

> "[The community must] Prohibit the use of fill for structural support of buildings within Zones V1-30, VE, and V on the community's FIRM."[44 CFR 60.3(e)(6)]

While fill is not allowed for structural support, a limited amount of fill is allowed for landscaping, local drainage needs, and to smooth out a site for an unreinforced concrete pad. Fill must not divert floodwaters or deflect floodwaters and waves beneath elevated buildings. Fill must also not divert floodwaters or deflect waves such that increased flood damages is sustained by adjacent and nearby buildings.

For further information on fill in coastal flood areas refer to FEMA Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program.*

3.7.3 Enclosed Areas and Breakaway Walls

The preferred method of constructing a V zone building is to leave the area below the elevated floor free of obstruction or to enclose the area only with latticework or insect screening. That way waves can freely flow under the building without placing additional loads on the foundation. The only solid foundation walls allowed below the lowest floor of a manufactured home in a V zone area are breakaway walls that will give way under wind and water loads without causing collapse, displacement, or other damage to the elevated portion of the manufactured home or supporting to the piles. The NFIP requirements for enclosures below an elevated building are:

> "[The community must] Provide that all new construction and substantial improvements within Zones V1-30, VE, and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purpose of this section, a breakaway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of breakaway walls which exceed a design safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions….." [44 CFR 60.3(e)(5)]

Just as in A zones, the space enclosed by walls is to be used solely for parking of vehicles, building access, or storage, and must be constructed with flood-resistant materials. Solid breakaway walls are allowed, as are garage doors that meet the same breakaway requirements. Solid breakaway walls are intended to collapse under the force of wave impacts without damaging the building's foundation or the elevated portion of the building. All solid breakaway walls should have their designs certified by a registered professional engineer or architect. The area enclosed by solid breakaway walls should be limited to less than 300 square feet because flood insurance rates increase dramatically for enclosures larger than 300 square feet.

For further information on enclosed areas and breakaway walls in coastal flood areas, refer to FEMA Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program* and Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program.*

3.7.4 Setbacks

44 CFR 60.3 (e)(3) requires the community to "provide that all new construction within Zones V1-30, VE, and V on the community's FIRM is located landward of the reach of mean high tide."

In coastal areas, there is a mean high tide line used for regulatory purposes. This means that the high tide line is physically shifting over time as beach and coastal areas are dynamic. However, the community, region, or State will have a regulatory line defined. The NFIP does not allow any development or construction to occur seaward of this line. Figure 3-7 illustrates how the mean high tide line defines the area of no development in coastal regions. Figure 3-8 shows coastal development in an area where setback requirements are enforced.

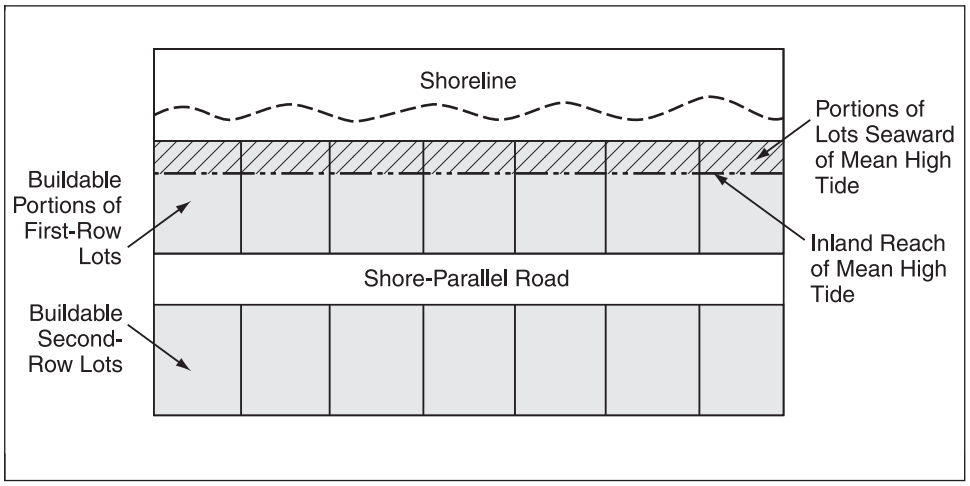

Shoreline
Portions of Lots Seaward of Mean High Tide
Buildable Portions of First-Row Lots
Inland Reach of Mean High Tide
Shore-Parallel Road
Buildable Second-Row Lots

Figure 3-7. Mean high tide line development restriction.

Figure 3-8. Coastal development well-suited to the land: generous setbacks, in combination with deep lots and avoidance of dune areas, should afford protection from erosion and flooding for years to come.

3.8 Existing Manufactured Homes in Flood Hazard Areas

3.8.1 Relocation

The best way to prevent damage to manufactured homes and to prevent loss of life and injury during a flood is to install manufactured homes outside of flood-prone areas. For existing manufactured homes, relocation of the manufactured home out of the floodplain may be a viable option to minimize damages.

Manufactured homes are relatively easy to transport and can be moved from areas prone to flooding to sites located outside of the flood hazard area. This not only allows the homeowner to prevent damage to the manufactured home, but also provides peace of mind concerning safety risks and property damages due to flooding.

Some issues to consider when evaluating relocation as a mitigation option include:

- Will it be cost-effective (cost of incurring damages versus cost of preventing damages)?
- Is the home in good enough condition for transporting?
- Is the removal of existing utility connections easily done prior to transportation?
- Is there a suitable new site for relocation?
- Are utilities with similar connections available at the new site?
- Is there a route that will provide adequate clearance for transporting the manufactured home?

The relocation process consists of nine steps that are fairly clear, but include many design considerations:

Step 1. Select a manufactured home moving contractor

Step 2. Analyze the existing site and manufactured home conditions

Step 3. Select, analyze, and design foundation for the relocated home at the new site

Step 4. Prepare the existing site

Step 5. Evaluate and plan the moving route

Step 6. Prepare the manufactured home for relocation

Step 7. Move the manufactured home

Step 8. Prepare the new site

Step 9. Restore the old site

More information on relocation as a retrofitting technique can be found in Chapter 7 of FEMA 312, *Homeowner's Guide to Retrofitting* (2nd Edition, 2009), and FEMA 259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures* (2nd Edition, 2001).

3.8.2 Evacuation

Evacuation of a manufactured home from a site when there is a flood threat can result in extensive flood damages being avoided to the home. Communities may have procedures in place for evacuating homes when there is a flood threat and may provide assistance to the occupant of the manufactured home to remove the manufactured home to a protected site. The NFIP will pay up to $1,000 for the reasonable expenses incurred to move an insured manufactured home to a place other than the described location that contains the manufactured home in order to protect it from flood or the imminent danger of flood. Any insured manufactured home moved

to a place other than the described location must be placed outside of the Special Flood Hazard Area or above ground level.

Communities may allow the evacuation of manufactured homes in Zones A1-30, AH, and AE only in the following cases:

- Evacuation of a manufactured home from an existing manufacture home park or subdivision; or
- Evacuation of a manufactured outside of a manufactured home park or subdivision.

After the threat of flooding from a specific event has passed, these manufactured homes can be returned to their original site without being elevated in accordance with the requirements at either 44 CFR 60.3(c)(6) or (c)(12) provided the manufactured home was not subject to the elevation requirements in these two paragraphs when first installed on the site.

Communities that allow existing manufactured homes to be removed to avoid flooding should have some type of permitting and tracking system in place to ensure that the same home is being returned to the original permanent site or pad. Communities may require a permit to ensure that utility reconnections meet local codes. If a community has developed a plan that pre-identifies manufactured homes that would be removed in the event of a flood, the plan should include procedures for determining which manufactured homes are to be removed and which ones are to be returned to their original site or pad. If a community has not developed a plan or individual manufactured homeowners initiate removal of their home on their own, the community is still responsible for determining whether the same home is being returned to the original site or pad. Since much can go wrong in trying to evacuate a manufactured home, evacuation is not a substitute for permanently protecting the manufactured home by elevating it to or above the BFE.

The community should issue some type of re-occupancy permit for owners who want to return the home to the original site or pad as a record to distinguish these from new or substantially improved manufactured homes that must meet the community's floodplain management regulations. A variance under the NFIP floodplain management regulations at 44 CFR 60.6(a) is not required for returning a manufactured home that was evacuated to the original site or pad because it is not a new placement, a replacement of, or substantial improvement.

3.8.2.1 Manufactured Home Substantially Improved or Returned to a Different Site or Pad in an Existing Manufactured Home Park

If the manufactured home that was evacuated due to the threat of flooding is placed on a different site or pad in the existing manufactured home park or subdivision or is substantially improved on the original site or pad, it would have to meet the requirements at 44 CFR 60.3(c)(12) in all A zones (the manufactured home would have to be elevated to the BFE or be elevated at 36 inches in height above grade).

3.8.2.2 Manufactured Home Placed in a New Manufactured Home Park or Subdivision

If the manufactured home that was evacuated due to the threat of flooding is placed in a new manufactured home park or subdivision or in the expanded part of an existing manufactured home park or subdivision, or is placed on a different site outside a manufactured home park or subdivision, it would have to meet the elevation requirements of 44 CFR 60.3(c)(6) in Zones A1-30, AE, and AH and elevate to the BFE or 44 CFR 60.3(e)(8) in Zones V1-30, VE, and V and elevate to the BFE.

3.9 HUD Manufactured Home Construction and Safety Standards

Prior to 1975, there were no Federal mandatory regulations or standards governing the design and construction of manufactured homes. Since 1976, HUD's Manufactured Home Construction and Safety Standards (MCHSS), or "HUD codes," have regulated the design and construction of factory-built manufactured housing.

After Hurricane Andrew in 1992, the HUD codes underwent many improvements regarding design and construction of manufactured homes. The lateral (wind) load provisions were updated to a modified American National Standards Institute/American Society of Civil Engineers (ANSI/ASCE) 7-88 design standard.

The HUD codes were revised to include three wind zones (Figure 1-1). Zone II homes are designed to resist a 100-mph (fastest mile) wind event; Zone III homes are designed for 110 mph. The design wind speed for Zone I homes is not specified. Rather, HUD I homes are designed to resist specified lateral and uplift wind pressures. Also, as point of interest, the HUD codes' energy design requirements were updated around this time frame. HUD codes program standards are found in 24 CFR 3280.

HUD's MHCSS include provisions for support and anchoring systems based on HUD Wind Zones I, II, and III. HUD's standards specify design requirements for the body and frame of the manufactured home. However, the HUD standards do not take seismic loading into account for the design of foundations and attachments.

The program has been in effect since 1976, and all manufactured homes built on or after June 15, 1976, are subject to HUD requirements. Although building codes are usually regulated at a local level, an exception is made with manufactured housing because it is most often built outside of the locality where it is eventually sited for use. Prior to the MHCSS, the quality of manufactured housing was unreliable, which resulted in the severe restriction or banning of the housing within several localities.

Under the program, manufacturers who build manufactured homes for sale in the U.S. are required to follow HUD-mandated design and construction standards. The standards are enforced either through HUD or approved Primary Inspection Agencies (either private firms or State administrative agencies) that perform reviews of manufacturers' designs and inspect the homes during construction to ensure compliance with the standards.

According to 24 CFR 3280, the purpose of the MHCSS is to establish standards for "all equipment and installations in the design, construction, transportation, fire safety, plumbing, heat-producing and electrical systems of manufactured homes which are designed to be used as dwelling units."

A manufactured home designed and constructed in accordance with the MHCSS standards will have a data plate and a certification label attached to it. The data plate will be affixed in a permanent manner near the main electrical panel or other readily accessible and visible location. The data plate contains the following information:

- The name and address of the home's manufacturing plant
- The serial number and model designation of the unit
- The date it was manufactured
- A list of the certification label numbers that are affixed to each transportable section
- A list of factory-installed equipment, including the manufacturer's name and the model number for each appliance
- Reference to the roof and wind load zones for which the home is designed

The certification label will be a 2-inch by 4-inch aluminum plate. The plate will be permanently attached to the home on the tail light end of the home, approximately 1 foot from the floor and 1 foot in from the road side. Figure 3-9 is a certification plate for homes built after June 15, 1976.

AS EVIDENCED BY THIS LABEL NO. FLA 753750
THE MANUFACTURER CERTIFIES TO THE BEST OF THE MANUFACTURER'S KNOWLEDGE AND BELIEF THAT THIS MANUFACTURED HOME HAS BEEN INSPECTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT AND IS CONSTRUCTED IN CONFORMANCE WITH THE FEDERAL MANUFACTURED HOME CONSTRUCTION AND SAFETY STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE. SEE DATA PLATE.

Figure 3-9. Certification plate for manufactured homes built after June 15, 1976.

Siting and installation requirements for manufactured homes are generally a State or local regulatory responsibility, where such regulatory authority exists. Some State and local regulations require licensed or registered installers, and/or require permits to be obtained prior to installation. Inspections are often required in conjunction with the permits, to ensure correct

installation. The new installation standards in Part 3285 dictate that manufacturers' installation instructions be approved by a Design Approval Primary Inspection Agency (DAPIA) and the protections contained therein meet or exceed all requirements of HUD's model installation standards. This requirement is to ensure that the purchaser has the correct procedures available for installing the manufactured home.

As part of the 1994 changes, the provisions for "Windstorm protection" in 24 CFR 3280.306 that address anchoring systems were also modified to be consistent with the revisions made for wind design requirements for manufactured housing in high-wind areas. This section of the standard requires that the manufacturer provide instructions, including drawings and specifications, detailing at least one acceptable system of anchoring the manufactured home that has been approved by a registered professional engineer or architect (24 CFR 3280.306(b)). Requirements are detailed in 24 CFR 3280.306 for the instructions and stipulate wind loading requirements for design. At this time, the standards do not instruct the designer to consider the forces of floodwaters or seismic loads when designing the foundation system.

3.10 HUD Model Manufactured Home Installation Standards

Siting and installation requirements for manufactured homes are generally a State or local regulatory responsibility, where such regulatory authority exists. Some State and local regulations require licensed or registered installers, and/or require permits to be obtained prior to installation. Inspections are often required in conjunction with the permits, to ensure correct installation. The new installation standards in Part 3285 dictate that manufacturers' installation instructions be approved by a Design Approval Primary Inspection Agency (DAPIA) and the protections contained therein meet or exceed all requirements of HUD's model installation standards. This requirement is to ensure that the purchaser has the correct procedures available for installing the manufactured home.

State Manufactured Home Installation Programs

>p lc G^kr^ov /--6) ^``loafkd ql ERA$p Lc$a`b lc J^krc^`qroba Elrpfkd Mold^jp) qeb cliiltfkd States have Approved or Conditionally Approved Manufactured Home Installation Programs: Alabama, Arizona, Arkansas, California, Kentucky, Ohio, Pennsylvania, South Carolina, Tennessee, Washington, and West Virginia.

The following States have submitted applications for Manufactured Home Installation Programs: Georgia, Idaho, Indiana, Kansas, Maine, Michigan, Minnesota, Mississippi, Nevada, New Jersey, New York, North Carolina, North Dakota, Oklahoma, Texas, and Virginia.

The Manufactured Housing Improvement Act of 2000 required that HUD establish minimum National Model Installation Standards (which were published in 24 CFR 3285 in October 2007). The Act also set out requirements that States must meet in order to continue to regulate manufactured home installation in their State. To be eligible, States must meet certain requirements as indicated in HUD's Installation Program published in June 2008, including a requirement that State Standards meet or exceed HUD's Model Installation Standards.

The installation standards in 24 CFR 3285 include requirements for pre-installation and installation considerations, site preparation, foundations, and home installation procedures. Additionally, standards on installation, preparation, and/or testing of optional features, appliances, utility system connections, and life safety features have been incorporated. The standard is designed for adoption and use by authorities who are responsible for the safety and health of manufactured home users. The standards address natural hazards (wind, flooding, and freezing) by incorporating the following requirements:

- A section on Installation of Manufactured Homes in Flood Hazard Areas states that FIRMs must be consulted prior to installation to determine a property's flood risk and identify whether floodplain development permits may be necessary.
- In areas prone to flooding, elevation and anchoring techniques are required, as well as consultation with a registered professional engineer and local authorities to ensure installation conforms to all applicable codes and regulations.
- Piers, anchoring, and support systems of the foundation in flood hazard areas must be capable of resisting loads associated with design flood and wind events.
- Oil storage tanks in flood hazards areas must be protected from damage by anchoring and elevation or other design.
- Appliances located on the outside of the manufactured home and air inlets must be elevated to or above the design flood elevation (DFE), which is defined in Appendix D.
- Special requirements for footings and foundations for manufactured home placement in freezing climates apply.
- The installer is required to secure the manufactured home against the wind according to the HUD codes.
- Anchor type requirements (longitudinal) for manufactured homes subject to higher winds (Wind Zones II and III) apply.
- Provisions for maximum diagonal tie-down strap spacing, dependent on the wind zone in which the property is located, apply.

The standard can be viewed online at http://www.nfpa.org/assets/files/PDF/CodesStandards/MHCCHUD/MHCCInstallationStandardsFinalRule.pdf.

In October 2007, HUD issued 24 CFR 3285 *Model Manufactured Home Installation Standards*, which regulates manufactured home installations.

The new standard creates a baseline standard for manufactured housing installation; it presents the minimum requirements for installation that must be equaled or exceeded by States and are also a minimum requirement for manufacturers' installation instructions.

Manufactured Home Installation Standards for Flood Hazard Areas

24 CFR 3285.302 also requires manufacturers to indicate in the installation instructions if the foundation specifications have been designed for flood-resistant considerations and, if so, the conditions of applicability for velocities, depths, or wave action; or to indicate if the foundations are not abpfdkba ql ^aa0bpp «l la il^ap+

Model Manufactured Home Installation Standards 24 CFR 3285.302 – Flood Hazard Areas requires:

> "…foundations, anchoring and support systems must be capable of resisting loads associated with design flood and wind events, or combined wind and flood wind events, and homes must be installed on foundation supports that are designed and anchored to prevent flotation, collapse, or lateral movement of the structure"

3.11 Model Building Code Requirements

Model building codes can be adopted and enforced by localities and States to specifically address manufactured housing installation. Two major building codes within the U.S. are the ICC's International Code Series, and NFPA 5000, Building Construction and Safety Code (2006). The International Code Series includes the IRC for 2006 (IRC 2006), which applies to one- and two-family dwellings. In addition, the IRC for 2009 (IRC 2009) is now available.

3.11.1 IRC 2006

The IRC 2006 is a comprehensive residential building code that includes provisions for development in the SFHAs that meet the minimum requirements of the NFIP. Appendix E of the IRC 2006 contains a section dedicated to "Manufactured Housing Used as Dwellings." Section 502 of this appendix describes requirements for foundation systems, which, in part, refer to the general provisions of the code. Under the IRC Appendix E, all footings for manufactured housing shall be as follows:

- Extend below the frost line
- Be constructed of materials specified by the code, including masonry and concrete
- Be made of solid material (concrete and masonry footings)
- Be designed in accordance with seismic specifications, including minimum reinforcements near the bottom of the footing, and specifications on joints between footings and stem walls if located in a Seismic Design Category D1 or D2 area
- Be elevated to the DFE for new and replacement manufactured homes

Appendix E, Section AE604.1 of the IRC 2006 also details requirements for anchorage installation. The code ground anchor requirements are:

- The load carrying portion of the ground anchors shall be installed to the full design depth and shall extend below the established frost line into undisturbed soil.
- The manufacturer's installation directions should provide preload requirements and load capacities for various soil types.
- Approved ground anchors must be capable of resisting an allowable working load 3,150 pounds in the direction of the tie plus a 50 percent overload or 4,725 pounds without

failure. Failure is considered to have occurred when the anchor moves more than 2 inches at a load of 4,725 pounds.

- Ground anchors designed to be installed so that loads on the anchors are other than direct withdrawal must be designed and installed to resist an applied design load of 3,150 pounds at 40 to 50 degrees from vertical without displacing the end of the anchor more than 4 inches horizontally.

Appendix E, Section AE605 of the IRC 2006 establishes performance requirements for ties, materials, and installation. The requirements include:

- Ties must be attached to ground anchors with turnbuckles or other adjustable tensioning devices, and
- Ties must be capable of resisting a working load of 3,150 pounds with less than a 2 percent elongation, and a 50 percent overload of 4,725 pounds.

FEMA has evaluated the IRC 2006 and has determined that it is consistent with NFIP regulations. The IRC 2009 has also been determined to be consistent with NFIP regulations.

3.11.2 NFPA 5000

NFPA 5000's Chapter 39 (Flood-Resistant Design and Construction) includes many of the minimum NFIP requirements. According to the code, manufactured housing located in the flood hazard area must adhere to the following requirements:

- Foundations must be designed and constructed as required by Structural Engineering Institute (SEI)/ASCE 24, *Flood Resistant Design and Construction.*
- In flood areas subject to high velocity wave action, structural fill, slabs-on-ground, and foundation walls are prohibited.
- The lowest floor of the structure must be elevated to or above the DFE (see Appendix D for DFE description).
- Manufactured homes must be installed using methods that minimize flood damage and shall be securely anchored to a foundation (meeting the requirements of SEI/ASCE 24). These requirements are in addition to the manufacturer's specifications and State and local anchoring requirements for resistance to wind.
- Where temporary structures are proposed, the authority having jurisdiction must consider flood warning time as well as the location of the structure in relation to any floodways, alluvial fan areas, or high velocity wave action areas before granting a permit.

NFPA 5000 also dictates that ASCE 7 is to be used to determine the design loads associated with environmental loads, including wind, seismic, snow, and ice events. The code states that all buildings and other structures shall be designed to resist these design loads.

3.11.3 NFPA 501

NFPA 501, *Standard on Manufactured Housing*, addresses the design, manufacture, and transportation of manufactured homes and adopts, by reference, ASCE 7-2002. NFPA 501 also added some seismic provisions by requiring all homes placed in seismic areas to have their water heaters braced to prevent falling or horizontal movement.

3.11.4 NFPA 225

NFPA 225, *Model Manufactured Home Installation Standard*, is the first multi-hazard installation standard for manufactured homes. NFPA specifies wind provisions (ASCE 7-02), includes provisions for homes sited in SFHAs, and contains the latest National Earthquake Hazards Reduction Program (NEHRP) criteria for homes susceptible to earthquake damages.

FEMA has evaluated the 2005 edition of NFPA 225 and has determined it is consistent with NFIP regulations. In addition, the 2009 edition of NFPA 225 is now available and has also been determined to be consistent with NFIP regulations.

4 Site and Development Options

Site evaluation is a critical step in the decision-making process of installing a manufactured home. Decisions are sometimes made without accurately assessing or considering a property's vulnerability to flooding and other hazards. By conducting a thorough site assessment, a property owner or developer can mitigate the following types of losses, damage, and associated problems:

- Injuries and loss of life
- Damage or loss to buildings and contents
- Damage to attendant infrastructure
- The need for emergency evacuation

A complete and detailed understanding of the advantages and disadvantages of potential sites for manufactured home installation helps lead to informed decisions; not all sites are suitable for development.

A thorough evaluation of property for development purposes is completed through a five-step process:

1. Compile lot/parcel information for one or more candidate properties.
2. Determine if local, regional, State, and Federal regulatory requirements allow the development and installation of a manufactured home and, if so, determine the requirements.
3. Identify the hazards present at the site (e.g., wind, flooding, seismic, etc.).
4. Determine whether potential effects from hazards could be avoided through siting, design, and construction and whether the residual risks to the site and the building are acceptable.
5. Proceed either with the purchase or development of a property, or reject the candidate site, and find and evaluate alternative sites.

Basic information about the property (e.g., lot size, zoning and land use requirements, and utility and infrastructure availability) enables the potential property owner or developer to assess if the site is suitable for development as a manufactured home site. If development is feasible, the potential property owner should conduct Steps 3 and 4 of the process to assess the property's hazard vulnerability. Based on the assessment findings, the property is determined to be either suitable or unsuitable for the installation of a manufactured home. The following sections provide additional information for the recommended assessment process.

4.1 Step 1: Compiling Site Information

After a site for possible purchase and/or development has been identified, basic information about the site is collected for a development analysis. It is vital that all pertinent information is collected in order to complete a thorough analysis.

Community building permitting or planning and zoning offices are helpful in steering potential property buyers toward information they need to evaluate a property. This is true of individuals looking at isolated lots or lots within existing manufactured housing subdivisions. A checklist of information to be collected is provided in Table 4-1. Not all of this information will be available for all sites and properties.

Although much of the information listed in Table 4-1 will need to be obtained locally, State and Federal government resources are also useful. Table 4-2 presents a partial listing of the most likely resources (i.e., local, regional, or State government) for obtaining specific information.

Table 4-1. Information Checklist

Property Location	
• Municipal, township, county, or other local jurisdiction	• Flood-prone area designation
• Street address	• Seismic hazard area designation
• Parcel designation (e.g., tax map ID)	• High-wind area designation
• Subdivision information	• Other hazards areas
• Special zoning or land use districts	• Natural resource protection area designation
Property Dimensions	
• Total acreage	• >`ob^db lrqpfab lc abpfdk^qba «llami^fk ^ob^ or other hazard-prone area
• Property shape	• Acreage landward/outside of natural, physical, or regulatory construction or development limits (i.e., usable acreage)
• Property elevations and topography	
• ll`^qflk obi^qfsb ql ^aq^`bkq molmboqfbp8 `lkªdro^qflk lc adjacent properties	

Table 4-1. Information Checklist (continued)

Legal and Regulatory Information	
• Land use designation at property and adjacent properties	• Local/State permitting procedures and requirements
• Wlkfkd `i^ppfª`^qflk ^ka obpriqfkd obpqof`qflkp lk rpb	• Local/State regulations regarding use, construction, and repair of erosion control measures
• Building codes and local amendments	• Riparian rights
• Floodplain management requirements	• Local/State restrictions on cumulative repairs or improvements
• Erosion hazard area: construction setback and regulations	• Conditions or other requirements attached to building or zoning permits
• Natural resource protection area: siting, construction, or use restrictions	• Subdivision plat covenants and other restrictions imposed by developers and homeowners' associations
• Easements and rights-of-way on property (including beach access locations for nearby properties or the general public)	• Hazard disclosure requirements for property transfer, including geologic hazard reports
• Local/State siting and construction regulations	
• Regulatory front, back, and side setbacks	
Physical and Natural Characteristics	
• Soils, geology, and vegetation – site and region	• Proximity to inlets and navigation structures
• Site drainage – surface water and groundwater	• Previous or planned community/regional beach/dune restoration projects (coastal)
• Storm, erosion, and hazard history of property	• Relative sea-level/water-level changes – land subsidence or uplift (coastal)
• Absbilm j bkq,mlqbkqf^i «lla ab_ofp rmpqob^ j ^ka adjacent to property	• Wind missile hazards – utility poles, trees
• Erosion control structure on site: type, age, condition, and history	
Infrastructure and Supporting Development	
• Access road(s)	• Sewer or septic
• Emergency evacuation route(s)	• Limitations imposed by utility, infrastructure locations on property use
• Electric, gas, water, telephone, and other utilities – on-site or off-site lines and hookup	
Financial Considerations	
• Intended use: owner-occupied or rental property	• Special assessments for community/association projects (e.g., private roads and facilities)
• Real estate taxes	• Maintenance and repair of private erosion control structures
• Development impact fees	• Increased building maintenance and repairs in areas subject to high winds or wind-driven rain
• Permit fees	• Building damage costs (insured and uninsured) colj mobsflrp pqlo j p) «llap) ^ka lqebo e^w^oa events
• Hazard insurance: availability, premiums, deductibles, and exclusions	
• Property management fees	

Table 4-2. Partial Listing of Local, Regional, and State Responsibilities

Local	Regional	State
Deeds and Property Records	Deeds and Property Records	Building Codes and Standards
Emergency Management	Emergency Management	Emergency Management
Environmental Protection	Environmental Protection	Coastal Zone Management
Building Codes and Permitting	Geographic Information Systems	Geologic Survey
Floodplain Management	Health	Floodplain Management
Planning and Zoning	Planning and Zoning	Natural Resource Management
Municipal Engineering	Post-storm Damage Assessments	Post-storm Damage Assessments
Soil and Geology	Soil and Geology	
Subdivision Review	Subdivision Review	
Tax Assessor	Tax Assessor	
Utilities	Utilities	

4.2 Step 2: Reviewing Basic Siting Information

After collecting pertinent site information, a thorough review of the information is necessary to ensure that development of the site is feasible. Particularly, building codes and planning and zoning codes requirements should be reviewed early in the evaluation process to verify that development of the property with the installation of a manufactured home is allowable. If installation is allowable, a review of requirements will assist in location of the manufactured home on the site.

4.3 Step 3: Hazard Analysis and Risk Assessment

A hazard analysis and risk assessment should be performed to determine what hazards exist for a particular area or site, and then the risk level for that site should be evaluated. It is important to consider flooding in this analysis as well as other hazards such as dam failure, land subsidence, seismic hazards, and severe wind.

For community-wide assessments, there are several FEMA tools available for use to conduct a Hazards Analysis and Risk Assessment, including the FEMA software Hazards U.S.–Multi-Hazard (HAZUS-MH) and *Mitigation Planning How-to Guides* (FEMA 386). Under the Disaster Mitigation

Act of 2000, communities are required to complete hazard mitigation plans, which include a hazard identification and risk assessment section, should they wish to remain eligible for post-disaster mitigation funding. As a result, many regional and local governments have already used tools like HAZUS-MH and the *How-to Guides* to conduct their own risk assessments, which may be available for public review.

4.3.1 Flooding

Table 4-3 presents a list of the types of hazards that can result from flooding and the flood sources or types of flood-prone areas where they are generally of concern.

Table 4-3. Flood Hazards

Flood Hazard	Associated Flood Hazard Areas or Property Characteristics
l lkd aro^qflk «l l afkd	• Large water bodies (rivers, bays) • Water bodies with slow drainage (lakes, ponds)
Inadequate storm drainage	• Flat or poorly graded land • l^ka il `^qba afob`qiv ^ag^``bkqqlq^ «l l a plro`b
Impact forces	• @l^pq^i ^ob^p pr_gb`qqlq t^sb ^`qflk «l l afkd • Ofsbofkb «l l afkd ^ob^p pr_gb`qqlq efde sbil `fqv «l l afkd
Efde sbil `fqv «l t p	• Coastal areas subject to wave action • Pqbbmiv*pilmba ofsbofkb «l l afkd ^ob^p lo ^ob^p lqebo t fpb pr_gb`qqlq efde sbil `fqv «l l a «l t p
Erosion	• Coastal areas subject to wave action • Pqbbmiv*pilmba ofsbofkb ^ob^p t fqe efde sbil `fqv «l l a «l t p lo ^ob^p lqebo t fpb pr_gb`qqlq efde sbil `fqv «l l a «l t p
Sediment deposition	• Coastal overwash areas
Movable stream beds	• Dynamic river systems
Flood depth	• >ob^p ^ag^``bkqqlq eb «l l a plro`b • Areas with poor capacity for drainage

Two of the best sources to research a property's susceptibility to flooding are the community's FIRM and FIS. The FIRM shows the extent of the 1-percent annual chance flood, and might also include flooding corresponding to the 0.2-percent annual chance flood (also known as the 500-year flood). For areas where detailed studies have been performed, FIRMs will also show BFEs along streams and may provide delineations of floodways.

An FIS summarizes the methods used to develop the hydrologic and hydraulic studies, which together determine the extent of the 1-percent annual chance floodplain. The FIS also presents a summary of results of the study, including information about floodwater surface elevations and velocities for detailed study areas. Figure 4-1 shows portions of an FIS and a FIRM.

The FIRM is used in conjunction with the FIS to determine the flood risk for a given area or property. For detailed study areas, while the FIRM shows the extent of the base flood and the BFEs, the FIS includes flood profiles that show flood elevations for various frequency events as well as the channel bottom elevation (for riverine flooding) over the length of a given waterway. If the property is located in the base floodplain where a detailed study has been performed, the FIRM and FIS will provide the following valuable information:

- The elevation of a base flood at a site as well as elevations for the 10-, 50- and 500-year floods, which can be found on the flood profiles within the FIS
- The average velocity of floodwaters within the floodway for a base flood (where a floodway study was performed)
- Areas of coastal wave action flooding
- Riverine flooding areas
- Areas susceptible to ponding
- Areas susceptible to sheet flow or alluvial fan flooding
- Areas protected by levees

Information about an area's susceptibility to flooding can also be gathered from community officials and past storm event records and reports. Such reports usually provide information about what types of damage were inflicted on structures. For coastal areas, there may be information about beach and shoreline erosion.

A field assessment for a particular site is a way to collect information for a hazard analysis. Information gathered during a field visit (ideally conducted by a geologist or an engineer) can be used to assess what type of impact such forces will have on a manufactured home located on a particular site. This is determined by assessing what type of structures and potential debris are located upstream and adjacent to the property that could impact the manufactured home during a flood event. A field assessment can also be conducted to estimate the erosion potential for a site by investigating existing land slopes on the site as well as vegetation cover. Finally, the site's grading/topography should be evaluated. As part of the assessment, it should be determined whether or not the site will drain in a reasonable amount of time in order to prevent long duration flooding. This issue is generally only relevant for smaller storm events or more localized flooding for which floodwaters have somewhere to drain.

4.3.1.1 Accessibility

The flood risk to both the manufactured home and access routes should be assessed. Inhabitants of manufactured homes in flood-prone areas should prepare to evacuate an area should a flood watch be issued by the local or State government and should not wait for flood conditions

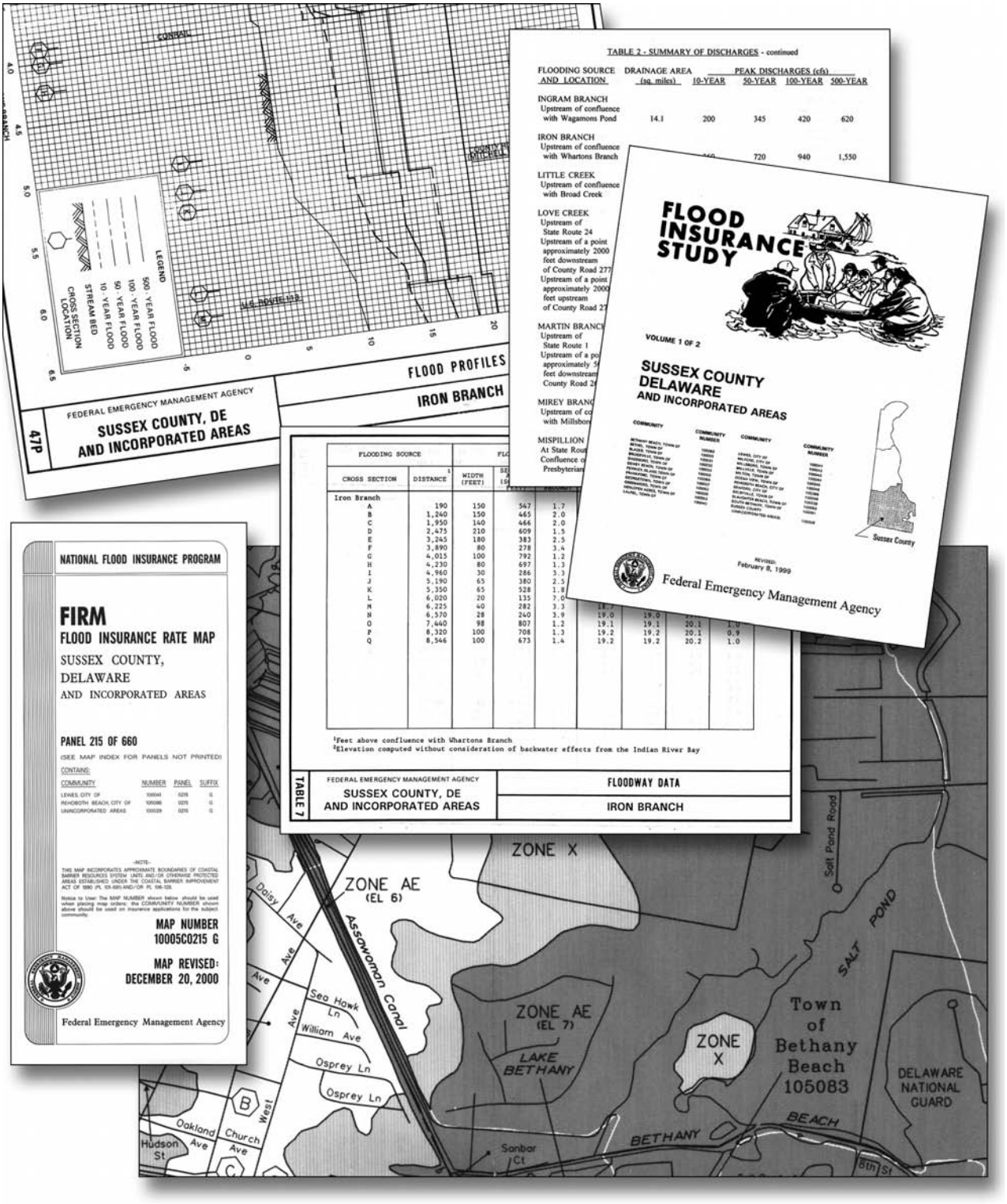


Figure 4-1. Portions of an FIS and a FIRM.

to begin before evacuating the area. In fact, drowning in vehicles is the number one cause of flood-related deaths and often happens when victims mistakenly think that a washed-out roadway or bridge is still open. Therefore, access to the manufactured home during flood events needs to be considered during the siting process.

Inhabitants of manufactured homes in flood-prone areas should *never* remain within the home during a flood, regardless of the home's elevation level above the BFE. They should always evacuate when a flood warning is issued by the local or State government and not wait for flood conditions to begin before evacuating the area.

Actual damage to roadways during flood events, as well as high-wind, seismic, and land subsidence events, can leave roads impassable for several days or for weeks after a major disaster. Even roadways that are located outside of, but adjacent to, flood-prone areas can be undermined by severe erosion along stream banks. Therefore, even if a home is adequately protected from incurring major damage due to a flood event, its location within (or surrounded by) a flood-prone area could either force occupants to repeatedly evacuate or become stranded for several days if access and egress routes are blocked.

A clear access and egress path during a flood event ensures that building occupants can evacuate and that emergency and critical services can continue to be provided. Both access and egress should be addressed while evaluating a potential site to ensure that feasible alternatives exist. Necessary considerations may also include bridges, walkways, and areas of refuge for safe evacuation.

Similarly, accessibility to potential sites after major wind and seismic events should be considered. After wind and seismic events, roadways can be blocked by debris and remain unusable for several days while cleanup efforts are underway. Potential property buyers or property owners should consider possible evacuation routes from the property in all cases.

It is important to note that accessibility is more than ingress and egress in an emergency. Frequent and long duration flooding can cause major problems for occupants of flood-prone structures; a site is not a good location for a manufactured home if its occupants are forced to evacuate several times a year due to a flood threat, or must stay out of their homes for days or weeks at a time when they do evacuate. Frequent and/or long-term displacement often results in significant financial hardships and emotional distress for flooding victims.

4.3.2 Other Hazards

In addition to flooding, there are a variety of other hazards that should be considered during the manufactured home siting process. Table 4-4 presents some of these hazards, their associated hazard-prone areas, and sources to use to determine an area's susceptibility. Historical storm or hazard event records are additional resources for this hazard analysis; they provide details on how hazards have previously affected a given area.

Table 4-4. Hazard-Prone Areas

Hazards	Associated Hazard Areas	Source for Determination
Dam failure	• Dam failure inundation areas located downstream of dam structures	• Dam failure inundation maps usually created at the State, regional, or local level
Land subsidence	• Steeply sloped land	• United States Geological Survey (USGS) Landslide Overview Map of the Conterminous United States (national level) • State Geologist • Local Public Works Director
Seismic	• Area within 6 miles of a known fault	• USGS Seismic Maps (as found in FEMA 450 and ASCE 7) • Building Codes
Wind/Debris	• Coastal areas • Tornado-prone areas • Alluvial fans	• Wind Zone Maps (as found in FEMA 320 and ASCE 7) • Building Codes

Dam failure inundation maps provide the best tool for determining the risk from a dam failure event and are usually available at the State or local level. Every State has a Dam Safety Officer responsible for coordinating its Dam Safety Program. State-specific information about State dam safety regulations is available at the Association of State Dam Safety Officials' web site: http://www.damsafety.org.

To avoid damage that can be caused in areas subject to land subsidence, manufactured homes should be sited away from steep slopes and areas where land subsidence has been known to occur in the past. While the USGS Landslide National Map indicates relative risk on a national basis, State geologists and local public work directors can provide better community-specific information about landslide risk. A listing of State geologists is available at the Association of American State Geologists web site: http://www.stategeologists.org.

USGS seismic maps as well as local officials are the best sources for determining the seismic risk for a site. The types of soils present on the site should also be taken into consideration. Poor soils, often found in flood-prone areas, can greatly amplify ground motions and seismic forces.

During wind events, large structures or items such as trees and telephone poles can be damaged and either collapse or become separated from their anchoring to the ground to become sizable pieces of debris. Manufactured homes should be sited away from or in a manner that provides protection from such items since airborne debris can act as missiles during a wind event.

Generally, coastal areas are susceptible to high winds from storm and/or hurricane events. A good reference to determine the susceptibility of a property to wind and seismic hazards is ASCE 7, which provides maps that show the risk of wind and seismic activity for the entire United States and detail design considerations for areas based on the risk posed by these hazards.

4.4 Step 4: Protecting Properties In and Near Hazard-Prone Areas

The best way to avoid damage to a manufactured home is to site the home away from areas susceptible to hazards. If the home is to be sited in or near a hazard-prone area, the developer must establish that the risk for the site is acceptable by ensuring that the home can be installed on the proposed site in accordance with applicable hazard-resistant codes and standards. In addition, mitigation techniques can be used during the installation process to further reduce the hazard risk.

NFIP floodplain requirements and HUD installation standards exist to lessen manufactured home vulnerability to flood hazards. Two aspects to consider during this process include the following:

- Placement options
- Design and construction techniques

4.4.1 Placement Options

One way to reduce the risk of damage to manufactured housing and attendant infrastructure is to select a site outside the limits of the hazard areas. This option is most applicable to areas subject to flooding and landslides where hazard areas can be reasonably well defined. Flood and landslide hazards are often localized so that all or a portion of the proposed site development can be located outside of the hazard-prone area. Note that this method is best suited for land that is initially subdivided or in the overall design of a manufactured home park.

4.4.1.1 Flood-Prone Areas

Within floodplain areas, portions of an individual site may be outside the defined floodplain. Portions of the site outside the identified floodplain typically have higher ground elevations and are less susceptible to flooding. Locating the manufactured home outside the identified flood hazard area reduces the home's exposure to the hazard. For individual sites located entirely within the flood-prone area, this method is not an option. Another option for siting in flood-prone areas is to determine if there are portions of the property that, while susceptible to flooding, are not exposed to some of the more destructive characteristics of flooding such as long duration flooding, high flood levels, and high velocity flows.

Generally, the farther a manufactured home is sited from the flood source, the less likely it is to be exposed to high velocity flows. Within riverine flooding areas, the highest velocity flows are usually recorded within and near the floodway. In areas vulnerable to coastal flooding, wave action and/or storm surge can cause floodwaters to be particularly destructive. These types of

forces are the strongest in FEMA high hazard coastal zones labeled as V zones on FIRMs and the portions of A zones adjacent to V zones.

Similarly, flood levels usually decrease as the distance from the flood source increases. Setbacks from the flood source help to keep structures out of areas most susceptible to high velocity and high depth flooding. Damage to structures is directly related to the depth of floodwaters to which they are exposed.

Additionally, floodwaters can make access to and from manufactured homes difficult both during and after a flood event and greatly increase the safety hazards of flooding. For this reason, manufactured home installation in the floodplain is strongly discouraged within areas of increasing flood depths (greater than 2 to 3 feet) and high velocity flood flow (greater than 5 fps).

The duration of flooding is generally dependent on the flood source (size of the watershed), the slope of the stream, and the type of flood event (e.g., hurricane, snow melt event).

Figure 4-2 shows a floodplain/floodway schematic. The floodway is generally the area where floodwaters are deepest and have the fastest flow rate for most waterways. Development in the floodway is restricted through floodplain management regulations and, in some communities, it is prohibited. Under minimum NFIP regulations, in order to place a new structure within the floodway, a floodplain development permit applicant must show that the development will not result in any increase to the 1-percent annual chance flood elevation. In most situations, development in the floodway is not permitted by communities because it almost always leads to a water surface elevation increase.

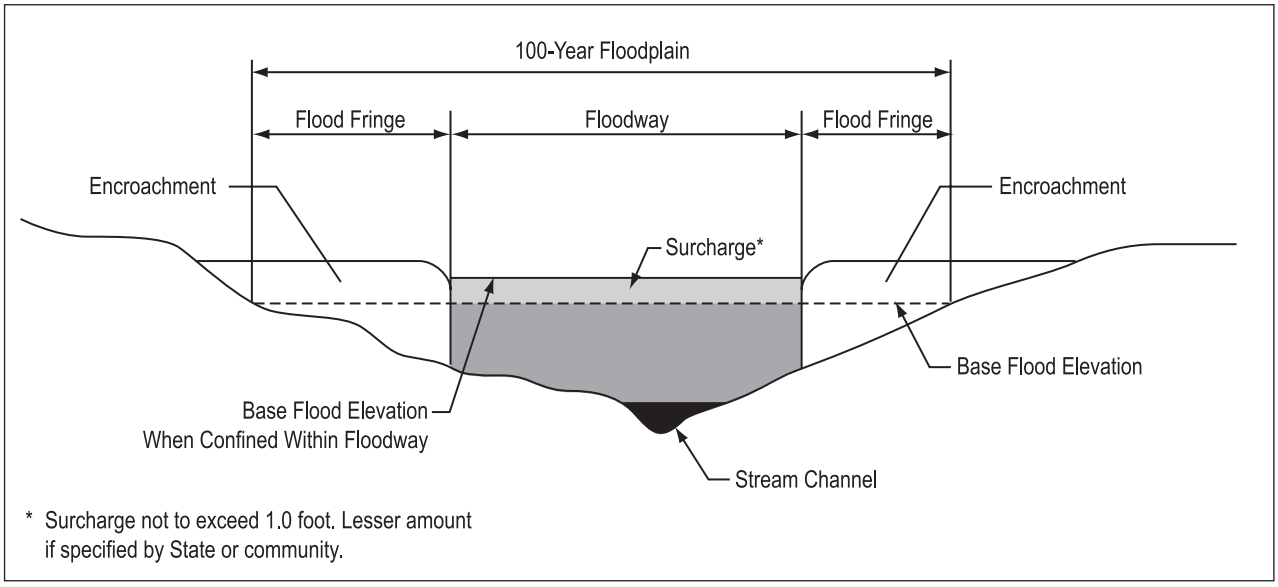


Figure 4-2. Floodplain/floodway schematic.

4.4.1.2 Areas Subject to Landslides

In areas subject to landslides, placing manufactured housing away from steeply sloped portions of a site, including relatively flat areas at the bottom of steep slopes, reduces exposure of the structure to damage. This is an option where landslides occur as the result of increased stresses from natural or manmade conditions. Some of the events or activities that can cause increased stresses include heavy rainfall, rapid snowmelts, melting of permafrost, groundwater withdrawal, soil liquefaction, and land development.

4.4.2 Design and Construction Techniques

A thorough review of design and construction techniques (as they relate to manufactured housing) and their applicability and feasibility is another consideration in the evaluation of site alternatives. A site located in a hazard-prone area cannot be deemed suitable for manufactured home installation if mitigation methods cannot be implemented at the site.

4.4.2.1 Flood-Prone Areas

Ideally, all manufactured homes should be located outside of the SFHA; however, if that is not possible, manufactured homes located in the SFHA must be installed to resist damage from flooding. Some questions for consideration in determining if design and construction techniques that prevent flood damage are feasible for a particular site follow:

- What are the flood risks for manufactured home installation at the site?
- Can structural fill be placed to elevate the site? If fill is placed, will it withstand forces from velocity flows?
- If long-duration flooding is an issue at the site, can the foundation be designed and constructed to resist long-duration floodwaters?
- Can the foundation be designed and constructed to withstand the expected design velocity flows?
- Can adequate storm drainage be provided?

Chapters 9 and 10 of this guide present methods for the design and construction of manufactured home foundations installed in flood-prone areas.

4.4.2.2 Dam Failure Inundation Areas

In dam failure inundation areas, the decision to install a manufactured home at the site will depend on assessment of the inundation risk. In higher risk areas where dam failures can trigger high flood depths and/or velocities, manufactured homes should be located elsewhere. High velocity flood surges can overwhelm typical residential foundation systems, including those used to support manufactured homes. However, in lower risk areas where relatively small flood depths and velocities are anticipated, the developer should determine if a foundation can be constructed that will provide adequate protection from expected inundation forces.

As with all hazards, safety issues such as warning times are also of vital importance.

4.4.2.3 Areas Subject to Landslides

Although it is preferable to site housing outside of areas vulnerable to damage from landslides, it might be feasible to undertake a grading project to reduce the risk of landslides. A developer must determine if this is feasible and consider whether it would be cost-effective. Licensed professionals specializing in earth movement (geotechnical, structural, and/or civil engineering) should be consulted.

4.4.2.4 Areas Subject to Seismic Events

For manufactured housing being placed in areas subject to seismic events, it is important to consider whether or not the foundation can be economically designed and constructed to withstand the expected forces for a design seismic event. Additionally, the property owner must consider the cost and effort of securing non-structural items in the manufactured home to prevent them from being damaged or dislodged. Relatively heavy items like domestic water heaters and HVAC units are particularly vulnerable to seismic events. Sewer, water, and gas lines should be sufficiently flexible to allow the home to move without damaging them. Inspections of manufactured homes after seismic events reveal that homes can be destroyed by broken utility connections (particularly natural gas connections) even where only minor damages occur to the home's structure.

4.4.2.5 Areas Subject to Wind/Debris Hazards

Manufactured housing being placed in areas subject to wind/debris events need to have a foundation that is designed and constructed to withstand the expected forces associated with a design wind event. In areas subject to seismic activity and wind, the design standard for the hazard requiring the most resistance should be used. Even if the design of a foundation to meet this requirement is cost- effective, the developer still must consider whether or not the manufactured home can withstand the forces expected from a design wind event and debris impact.

4.5 Step 5: Deciding on Property Development: Proceed or Reject

After reviewing the results of the data/information in Steps 1 through 4, deciding whether property development continues is the last step. Is the property suitable for development and for the installation of a manufactured home? If the siting evaluation shows that development of the property is feasible, and a hazard analysis and risk assessment also indicates development may be feasible, the proposed installation must be designed and constructed to adequately resist the hazard threat. If the proposed site satisfactorily addresses all of the conditions listed above, the site can be considered suitable for manufactured home installation.

5 Natural Hazards – Design Considerations

Many regions in the U.S., such as coastal areas, are subjected to severe flooding and wind events at the same time. Other areas are simultaneously subjected to snow and seismic loads. Manufactured homes can be subjected to more than one hazard at the same time and should be designed to appropriate concurrent loading (or load combinations) based on ASCE 7 design standards. However, *Manufactured Home Construction and Safety Standards* (24 CFR 3280) do not require that designs include simultaneous flood and earthquake loads. The MHCSS specifies that snow loads shall not be considered as simultaneously acting with the wind loads. HUD standards also require that foundations for manufactured homes be designed to resist loads for combined wind and flood events.

The first part of this chapter describes what kind of information is provided in FIRMs and FIS reports. The remainder of this chapter describes the characteristics of several natural hazards (flood, wind, and earthquake) that must be considered when making decisions about siting and selecting a foundation system for a manufactured home.

5.1 Flood Data

FIRMs and FIS reports are two sources that can provide vital information about flooding characteristics. Both of these tools are generally available for viewing at community permitting offices such as Zoning and Planning Departments or Building Permit Offices. The local permit official can go over these tools and help to explain floodplain development requirements. These tools are also available from FEMA's Map Service Center and can be accessed online at http://store.msc.fema.gov.

FIRMs provide key information about a property's flood vulnerability by showing the extent of the floodplain, the flood zone, the floodway (when floodway studies are performed), and the BFE (for detailed studies). Figure 5-1 shows an example of a FIRM. For example, Point 1 (white box) is located in the AE zone and has a BFE of 9 feet. For rivers and streams, FIS reports contain stream profiles that provide more accurate BFE data and should be used when determining BFEs for manufactured home installations or other types of development.

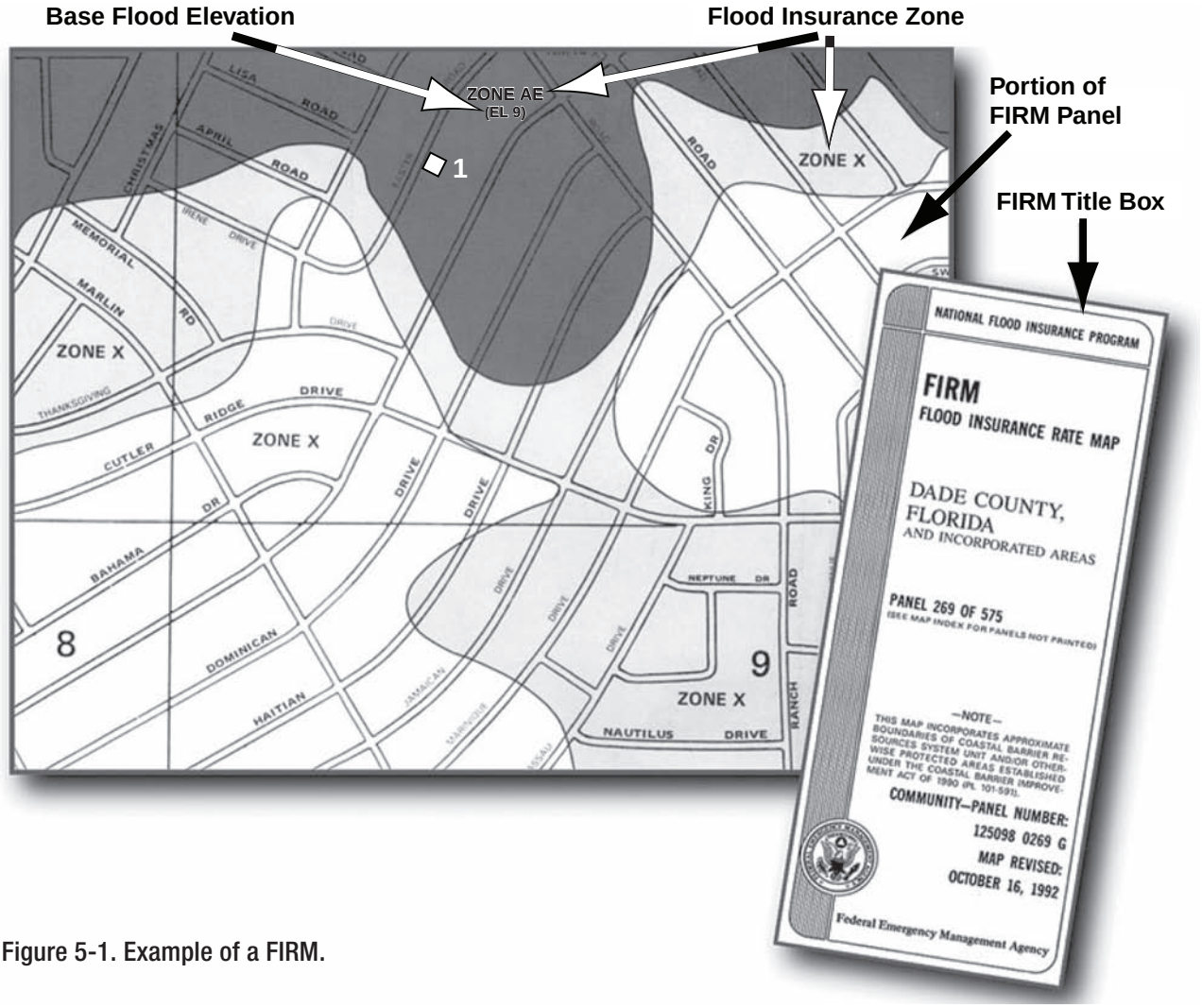


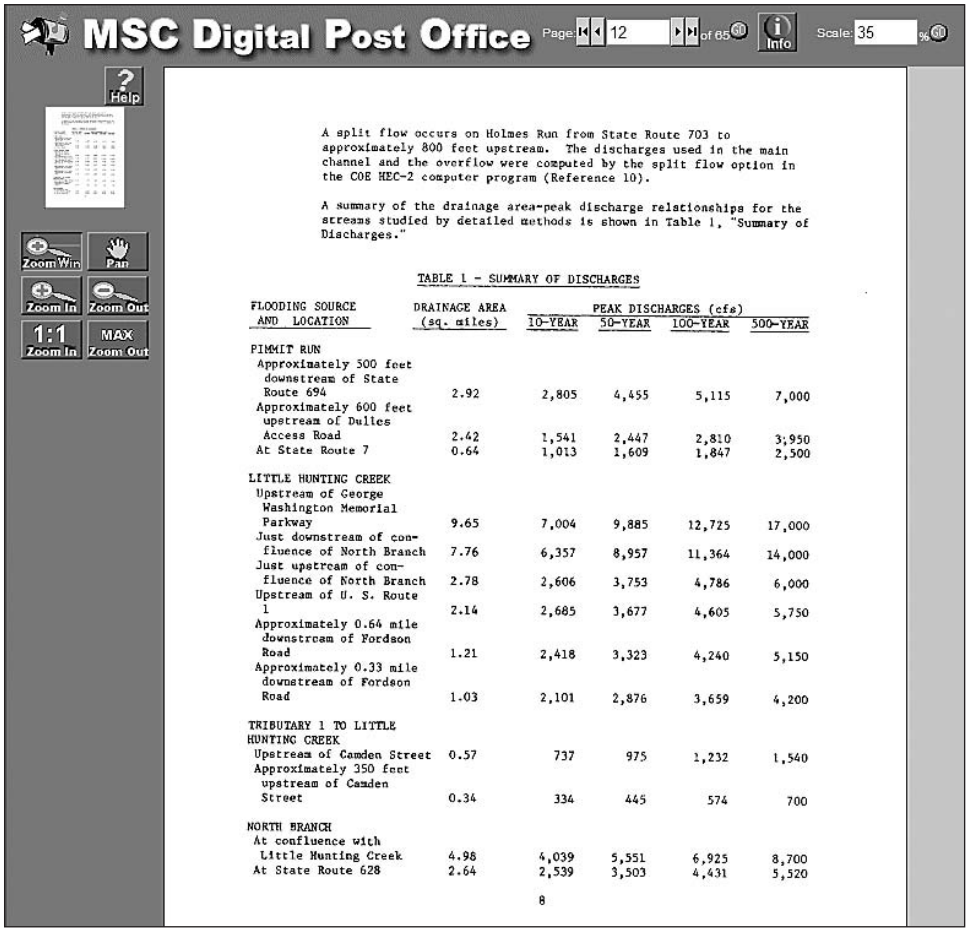
Figure 5-1. Example of a FIRM.

There are two principal digital options for using flood maps. The simplest option is FIRM Scan data. These are simply digital images of a map and are available everywhere FEMA has a published FIRM. FEMA provides tools to view these maps and create a FIRMette, which is a printout of the area of interest, along with FIRM title block, scale bar, and north arrow. There is an online FIRMette tool that allows you to find, view, and print any map when you need it. There is also a Desktop FIRMette tool that can be faster and easier to use if you frequently use the maps for one area or need to use them without an internet connection. You can download or order the FIRMette Desktop and FIRM Scans you need.

The second digital option is flood data in GIS format. GIS technology provides powerful abilities to create custom maps and perform sophisticated analyses. It also requires the user to have specialized skills and software to use. FEMA now produces a GIS product called the DFIRM Database for use with all map updates. Beginning on or after October 1, 2009, FEMA will provide a single paper flood map and FIS to each mapped community. FEMA will convert all other distribution of maps and FIS reports for digital delivery. FEMA will continue to provide free digital map products and data to Federal, State, Tribal, and local NFIP stakeholders.

FIS Reports

Several key components of an FIS report can help users identify specific flooding characteristics. For example, summary of discharge tables report the flow rate of water within streams for a given frequency storm (Figure 5-2). These values can be used with updated topography and cross-section information to conduct hydraulic modeling and to estimate updated flood elevations.[1] FISs generally generate water surface elevations for the 10-year (10-percent annual chance), 50-year (2-percent annual chance), 100-year (1-percent annual chance), and 500-year (0.2-percent annual chance) floods (Figure 5-3). Floodway data tables provide cross-section specific information, including the width of the floodway, mean floodway velocity, and the BFE where there is no encroachment in the flood fringe (or the regulatory BFE) and where there is full encroachment in the flood fringe (Figure 5-4). However, these tables are only available when a floodway study has been performed. See Appendix C for additional information.



A split flow occurs on Holmes Run from State Route 703 to approximately 800 feet upstream. The discharges used in the main channel and the overflow were computed by the split flow option in the COE HEC-2 computer program (Reference 10).

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 1, "Summary of Discharges."

TABLE 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
PIMMIT RUN					
Approximately 500 feet downstream of State Route 694	2.92	2,805	4,455	5,115	7,000
Approximately 600 feet upstream of Dulles Access Road	2.42	1,541	2,447	2,810	3,950
At State Route 7	0.64	1,013	1,609	1,847	2,500
LITTLE HUNTING CREEK					
Upstream of George Washington Memorial Parkway	9.65	7,004	9,885	12,725	17,000
Just downstream of confluence of North Branch	7.76	6,357	8,957	11,364	14,000
Just upstream of confluence of North Branch	2.78	2,606	3,753	4,786	6,000
Upstream of U. S. Route 1	2.14	2,685	3,677	4,605	5,750
Approximately 0.64 mile downstream of Fordson Road	1.21	2,418	3,323	4,240	5,150
Approximately 0.33 mile downstream of Fordson Road	1.03	2,101	2,876	3,659	4,200
TRIBUTARY 1 TO LITTLE HUNTING CREEK					
Upstream of Camden Street	0.57	737	975	1,232	1,540
Approximately 350 feet upstream of Camden Street	0.34	334	445	574	700
NORTH BRANCH					
At confluence with Little Hunting Creek	4.98	4,039	5,551	6,925	8,700
At State Route 628	2.64	2,539	3,503	4,431	5,520

8

Figure 5-2. FIS Summary of Discharges table.

1 Hydraulic modeling can be performed to estimate updated flood elevations where new or more accurate topography data are available. However, if the modeling shows lower flood elevations, they cannot be used for regulatory purposes unless a map revision (e.g., Letter of Map Amendment (LOMA) or Letter of Map Revision [LOMR]) is granted.

Figure 5-3. FIS Stream Flood Profile.

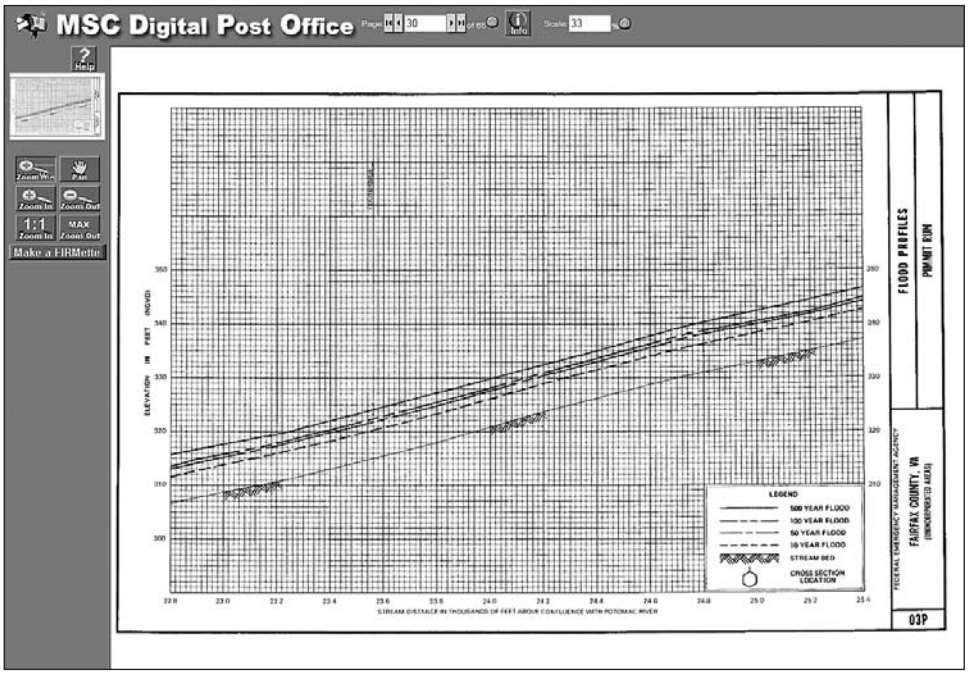
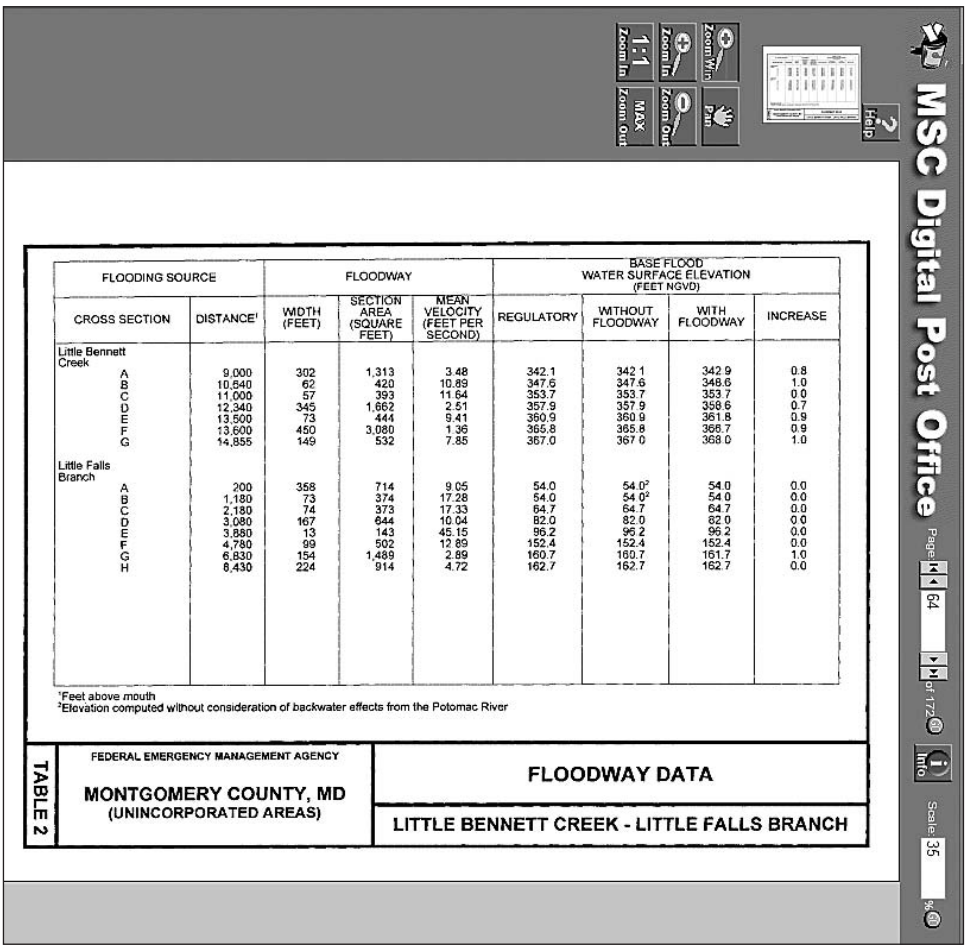


Figure 5-4. FIS Floodway Data table.



FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NGVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Little Bennett Creek								
A	9,000	302	1,313	3.48	342.1	342.1	342.9	0.8
B	10,540	62	420	10.89	347.6	347.6	348.6	1.0
C	11,000	57	393	11.64	353.7	353.7	353.7	0.0
D	12,340	345	1,662	2.51	357.9	357.9	358.6	0.7
E	13,500	73	444	9.41	360.9	360.9	361.8	0.9
F	13,600	450	3,080	1.36	365.8	365.8	366.7	0.9
G	14,855	149	532	7.85	367.0	367.0	368.0	1.0
Little Falls Branch								
A	200	358	714	9.05	54.0	54.0[2]	54.0	0.0
B	1,180	73	374	17.28	54.0	54.0[2]	54.0	0.0
C	2,180	74	373	17.33	64.7	64.7	64.7	0.0
D	3,080	167	644	10.04	82.0	82.0	82.0	0.0
E	3,880	13	143	45.15	96.2	96.2	96.2	0.0
F	4,780	99	502	12.89	152.4	152.4	152.4	0.0
G	6,830	154	1,489	2.89	160.7	160.7	161.7	1.0
H	8,430	224	914	4.72	162.7	162.7	162.7	0.0

[1]Feet above mouth
[2]Elevation computed without consideration of backwater effects from the Potomac River

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MONTGOMERY COUNTY, MD
(UNINCORPORATED AREAS)

FLOODWAY DATA

LITTLE BENNETT CREEK - LITTLE FALLS BRANCH

5.2 Flood Characteristics

A variety of factors contribute to the type and strength of flood forces. For instance, structures and their foundations are subject to different forces if they are flooded by standing or slowly moving floodwater versus high velocity or wave action flooding. Similarly, factors such as the duration of flooding and flood depth help to define how structures and foundations will be affected by flood events.

5.2.1 Frequency, Duration, and Rate of Rise

Frequency of flooding is the rate of flood occurrence at a particular location. This frequency is the probability, expressed as a percentage, that a flood of a specific size will be equaled or exceeded in any year. For example, the flood that has a 1-percent probability (1 in 100) of being equaled or exceeded in any given year is referred to as the "base flood" and sometimes called the "100-year flood;" the latter term is simply a convenient way to express probability. The base flood is particularly important for homeowners because it is used by the NFIP to determine flood insurance rates and define regulatory floodplain management requirements.

A 1-percent annual chance flood is a probability term and does not mean that a flood will happen approximately once every 100 years. Nor does it imply that once a 1-percent annual chance flood occurs there is little chance of another 1-percent annual chance flood occurring in the near future. To the contrary, changes in climatic conditions, such as those caused by El Niño or La Niña, often result in a cluster of floods that occur over relatively short periods of time at the same location.

Manufactured homes located within the 100-year floodplain on a FIRM might also be in the 10- or 5-year floodplain and subject to even more frequent flooding. Although more frequent floods such as the 10- or 20-percent annual chance flood (10- or 5-year flood) cause less damage to the manufactured home than the 1-percent annual chance flood, the repetitive damages can result in significant financial loss to the homeowner. Data describing the extent of more frequent but less intense flooding is also important in determining the foundation system most appropriate for resisting forces imposed by the smaller floods.

Information about the base flood can be found in the FIS and the FIRM, including the flood elevation and the extent of flooding. In areas where detailed studies have been performed, flood elevation information may also be available for the more frequent 10- or 2-percent annual chance flood as well as the less frequent 0.2-percent annual chance flood (500-year flood).

For historical flood events, flood frequency estimations are sometimes found in the FIS under the Principal Flood Problems section. Documentation of past flood events is sometimes available from other Federal sources as well as State and local agencies. Table 5-1 lists such sources and agencies.

Table 5-1. Sources for Information About Past Flood Events

Other Federal Sources	State Agencies	Local or Regional Agencies
USACE Floodplain Information Reports	Departments of Environmental Conservation/Protection	Flood Control Districts
USGS Water Resources Investigations	State Floodplain Management L¢a`b	Levee Improvement Districts
Natural Resources Conservation Service (NRCS) Watershed Studies	Departments of Natural Resources	Local Planning Commissions
Federal Highway Administration (FHWA) Floodplain Studies	Departments of Transportation	Local Public Works Departments
Tennessee Valley Authority (TVA) Floodplain Studies	Departments of Water Resources	Municipal Utility Districts
	Geologic Surveys	River Basin Commissions
		Water Control Boards

Flood duration is the time from the inundation to the recession of floodwaters. Flood duration provides an estimate of how long a manufactured home's foundation (not the home itself, assuming the home is properly elevated) will be subjected to pressures and forces exerted by floodwaters, the degree of floodwater seepage, and the length of time that a structure may be inaccessible and/or inhabitable for the occupants. For identical flood characteristics, long duration flooding is usually much more destructive than short duration flooding.

The rate of rise is a measure of how rapidly water depths increase during flooding. A slow rise of floodwaters will allow seepage of water into a manufactured home (only if it is not elevated above the flood level) and may prevent buoyancy forces from acting on a home. When water rises rapidly, however, there may be insufficient time for seepage, exposing the home to buoyancy forces. The buoyancy forces could result in failure of the foundation, the floor, or the framing of the home.

The rate of rise (and fall) also affects the amount of warning for an impending flood. For example, homeowners in the floodplains of large rivers like the Mississippi may know days in advance of upstream flooding that will eventually reach their homes. But in the floodplains of streams with high rates of rise, homeowners may have only a few hours' notice (or none at all) of an approaching flood.

The rate of rise and fall is important in planning emergency evacuations and determining the feasibility of emergency loss mitigation procedures. Although surrounding and upstream terrain is a good indicator of the rate, flooding duration for particular areas is best determined from historical data and accounts of past flood events. This information might be available locally from accounts given by homeowners and local emergency management staff, or it may be documented in the FIS or local, State, or Federal studies. See Table 5-1 for a list of potential sources of information.

5.2.2 Flood Elevation and Depth

The BFE is the elevation of the flooding, including wave height, if applicable (in V zones), having a 1-percent chance of being equaled or exceeded in any given year. The elevation of the flooding is the floodwater's height above or below an established reference datum. Ground elevation is the height of the ground surface also above or below an established reference datum. The standard datum used by most Federal agencies and many State and local agencies are the NGVD 29, and the NAVD 88; however, other datum are used. Ground elevations are established by topographic surveys; flood elevations are calculated for a particular flood event. BFEs can be found on FIRM panels where a detailed study has been performed, and should be estimated using the flood profile in the corresponding FIS.

BFE and DFE

?^pb «l l a bibs^qf l k %?CB& – The water surface elevation resulting from the base, or 100-year (1 per- `bkq ^kkr^i `e^k`b& «l l a+

Abpfdk «l l a bibs^qf l k %ACB& ¬ Qeb bibs^qf l k ql t ef`e absbi l m j bkq fk qeb obdri^ql ov «l l ami^fk fp built. At a minimum, the DFE is equivalent to the BFE. However, in some areas, the DFE includes an additional freeboard height above the BFE as shown in the formula below.

DFE = BFE + Freeboard

Freeboard – An additional elevation requirement some height (1, 2, or more feet) above the BFE that provides a margin of safety above the estimated BFE.

As indicated above, the minimum DFE requirement for NFIP communities is the BFE. However, in communities where a higher degree of protection is promoted or required, the DFE includes a freeboard height above the BFE. This freeboard provides a margin of safety above the estimated BFE and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties. The NFIP encourages participating communities to adopt and enforce freeboard obnrfob j bkqp ^p m^oq lc qebfo il `^i «l l ami^fk j ^k^db j bkq loafk^k`b+ Qefp fp pe l t k fk 11 @CO 3-+.%a&8 t ef`e pq^qbp) ¦>kv «l l ami^fk j ^k^db j bkq obdri^qf l kp ^a l mqba _v ^ Pq^qb lo ^ `l j j rkfqv t ef`e ^ob more restrictive than the criteria set forth in this part are encouraged and shall take precedence."

Some flood zones are delineated by approximate methods without BFEs determined. When a manufactured home is proposed on an approximate A zone site, the community must make every effort to obtain, review, and reasonably utilize BFE data and floodway data from a Federal, State, or other source in order to provide a reasonable measure of flood protection in accordance with 44 CFR 60.3(b)(4). If BFE or floodway data cannot be obtained from available sources, the community should consider conducting or requiring the applicant to conduct a site-specific engineering analysis to determine a BFE or floodway. FEMA has developed *Quick-2: Computation of Water Surface Elevations in Open Channels*, which is useful in developing a BFE. *Quick 2* is available from the FEMA web site http://www.fema.gov/plan/prevent/fhm/dl_qck22.shtm. If no BFE data are available through Federal, State, or other sources, communities must

ensure that building sites will be reasonably safe from flooding for proposed developments. A simplified method for estimating BFEs as well as other methods for ensuring a building site is reasonably safe from flooding can be found in FEMA 265, *Managing Floodplain Development in Approximate Zone A Areas, A Guide for Obtaining and Developing Base (100-year) Flood Elevations.* Additional guidance on approximate A zones and requirements for developing BFEs in subdivision proposals and other proposed developments can be found in Section 3.6.1.

Flood depth is the difference between the water surface elevation and the grade elevation of the flooded area (Figure 5-5). Any differences in datum between the flood elevation and the grade elevation must be taken into account when calculating flood depths.

Many communities have adopted more stringent requirements for an additional elevation (e.g., 1 foot, 1.5 feet, etc.) above the BFE. The additional height (or freeboard) is used to establish the DFE. Freeboard provides a margin of protection above the estimated base flood.

5.2.3 Hydrostatic (Buoyancy) Forces

For manufactured homes that are not elevated to above the BFE or DFE, hydrostatic forces can cause significant damages. Hydrostatic pressures are also a concern for enclosed areas underneath elevated manufactured homes.

When a body or a structure is immersed in water, the body is subjected to forces exerted by the surrounding water. These forces are called hydrostatic forces and act perpendicular to the surface on which they are applied. For example, hydrostatic forces exert lateral forces on vertical walls and vertical forces on horizontal floors.

The total vertical force (also called buoyancy force) on a submerged structure is equal to the weight of the displaced volume of water. For each foot of fresh water submersion, a buoyancy force of 62.4 psf is created. Salt water, with a greater density than fresh water, creates 64 psf for each foot of submersion. That is

$$F_{buoy} = \gamma \times V_{OL}$$

Where: γ = specific weight of water (62.4 pcf for fresh water; 64 pcf for salt water)

V_{OL} = volume of water displaced by the submergence object (ft^3)

The lateral force of water acting against a surface is related to the water's depth (d) and specific weight (γ). Hydrostatic forces create a triangular loading on vertical surfaces with zero psf on the water surface to a force equal to γ (pcf) multiplied by d (feet).

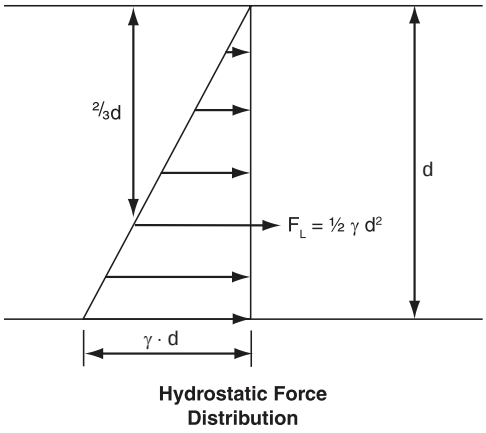
$$F_L = \tfrac{1}{2} \gamma d^2$$

Where: F_L = lateral force

γ = specific weight of water (pcf)

d = depth (ft)

F_L is applied at a distance 2/3 d from the water's surface.



Hydrostatic Force Distribution

Hydrostatic forces act perpendicular to submerged surfaces. If the water depth is the same on both sides of a wall, the lateral component of hydrostatic forces are equal such that the resultant force is zero.

If floodwater rises above the lowest floor, hydrostatic forces can lift an inadequately anchored manufactured home off its foundation. If buoyancy forces exceed the weight of a manufactured home, the home will float off its foundation if it is not securely fastened to the foundation. Floods do not need to be deep to displace a home. Flood depths of only 4 to 5 inches above the lowest floor can be capable of floating unsecured manufactured homes off their foundations.

The walls and floors of manufactured homes are not typically designed to resist hydrostatic forces, which can cause extensive structural damage. Floodwaters in contact with a home generally seep into it through openings around doors, windows, vents, and utility entrances. Floodwaters inside the structure add weight to the structure, thus reducing the net buoyancy force of the structure. Figure 5-5 shows hydrostatic forces acting on the walls and lowest floors below the flood level. As illustrated in Figure 5-5, an effective method of avoiding damage from hydrostatic forces is to elevate the home above the flood levels.

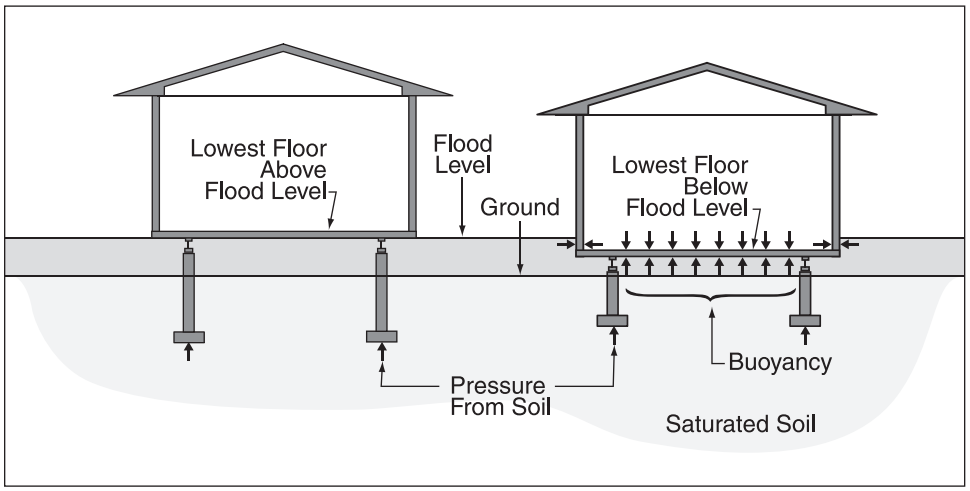


Figure 5-5. Buoyancy forces acting on a structure.

5.2.4 Hydrodynamic Forces

Forces due to moving floodwaters are called hydrodynamic forces. The magnitude of these forces depends on the floodwater depth, floodwater velocity, and the drag coefficient. Higher

depths and velocities produce greater hydrodynamic forces. The drag coefficient is a function of the shape of the body subjected to the hydrodynamic forces.

Moving floodwaters can cause foundation failure by pushing (sliding failure) (Figure 5-6) or by overturning. Either can topple foundation elements and destroy a home. In addition, moving floodwaters can cause erosion and scour that can undermine foundation elements (Figure 5-7).

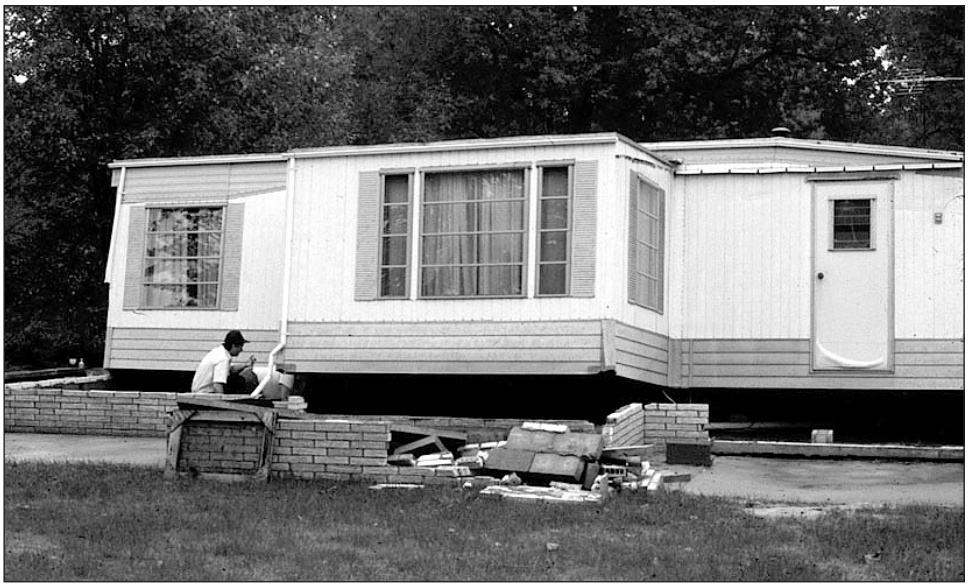


Figure 5-6. Failure due to sliding.

Figure 5-7. A manufactured home destroyed by the hydrodynamic forces of flooding.

Flood velocity depends on the slope and roughness of the terrain. For example, water moves faster along streams in steep mountains than streams in flatter areas, and water moves faster over a parking lot with a paved surface as opposed to an area with dense vegetation or other obstacles. Flood velocities are not shown on the FIRMs, but can be found in the FIS for floodways

where floodways have been studied. Mean floodway velocities can be obtained from the FIS by matching the cross-section on the FIRM with the cross-section in the floodway data table. The floodway's mean velocity usually overestimates the flood velocity within the flood fringe; floodwaters generally move slower as they extend outward from the floodway. However, the floodway velocities can be used as a general measure to determine cross-section locations within the floodplain where floodwaters will move relatively faster or slower, and provide an upper limit for velocities in the flood fringe. One of the best sources for flood velocities is records of past flood events. In addition to the FIS, a list of potential sources for documentation of past flooding is included in Table 5-1.

Coastal areas are particularly hazardous because of flooding accompanied by wave impacts that are associated with storm surges from coastal storms. Flow velocity can be further increased by manmade or natural obstructions that restrict floodwaters and channel the flow.

The hydrodynamic force exerted by a fluid in the direction of the flow stream is defined as the drag force F_d. Hydrodynamic forces are calculated as follows:

$$F_d = \frac{C_d \text{ x } A \text{ x } \gamma \text{ x } V^2}{2g}$$

Where: F_d = hydrostatic force (pounds)

C_d = dynamic coefficient (1.25 for round piers; 2.0 for square or rectangular piers; 1.4 for continuous foundations)

γ = specific weight of water

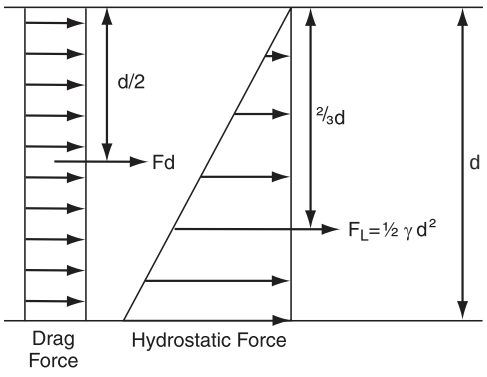
g = acceleration due to gravity (32.2 ft/s^2)

V = floodwater velocity (fps)

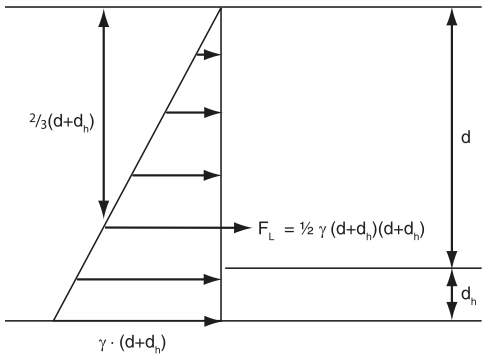
A = projected vertical area submerged (sq. ft.)

A = d x w

w = width of the submerged object



Hydrostatic and Hydrodynamic Force Distribution



Equivalent Hydrostatic Load Approach to Consider Hydrodynamic Force

An alternative approach to consider the dynamic effects of moving water is to use an equivalent hydrostatic load approach. When water velocities are less than 10 fps, ASCE 7 permits adding an equivalent surcharge water depth to the design flood elevation to simulate the hydrodynamic load.

The equivalent surcharge water depth (d_h) is determined by:

$$d_h = \frac{C_d \text{ x } V^2}{2g}$$

Where: C_d = dynamic coefficient (1.25 for round piers; 2.0 for square or rectangular piers; 1.4 for continuous foundations)

V = average velocity of water (fps)

g = acceleration due to gravity (32.2 ft/s^2)

Hydrodynamic forces apply to any portion of the home or its foundation exposed to moving floodwaters. Elevating the home so that its lowest floor is at the BFE reduces the effects of hydrodynamic forces on the building envelope. However the floor framing, chassis frame, and the foundation elements remain exposed to the hydrodynamic forces. For open foundations, elevating the home so the lowest chassis frame member is at the BFE reduces the effects of hydrodynamic forces by reducing the number of components exposed to those forces during a base flood event.

5.2.5 Erosion and Scour

Erosion is the result of moving waters removing soil from the ground surface. Scour is the result of those moving waters removing soil beneath and around objects located in the path of flow. Scour under and around building foundations and erosion of fill embankments can result in foundation failure. For example, when Hurricane Ike struck Galveston, Texas, in 2008, several homes were destroyed due to a loss of lateral support of pile foundations caused by scouring. Moving floodwaters will erode soil around any obstruction placed in the flow until a maximum scour depth is reached. The maximum scour is a function of flow velocity, soil particle size, and obstruction geometry. Determining maximum potential scour is critical in designing a foundation system that prevents failure during and after flooding. In coastal areas, scour depth can be significant due to both storm-induced erosion and localized scour resulting from storm surge. Because storm-induced erosion is difficult to predict, local regulatory officials should be contacted for further information and historical perspectives.

Scour susceptibility is a function of foundation geometry, flow depth, flow velocity, and the soil particle size. Fine grain soils (i.e., silts and clays) scour at a lower flow velocity than coarse grain soils. Coarse grain, non-cohesive soils can erode and/or scour quickly, possibly reaching the ultimate scour depth in a single flood event. Fine grain, cohesive soils can scour just as deep but take longer to reach the ultimate depth. It is important to note that foundations frequently are well above the ultimate scour depth and that foundation undermining can occur in a relatively short time period. Undermining of foundations can result in the collapse of the home.

Because flood velocities are not shown on FIRMs, the FIS must be consulted to determine flood velocities, which are only provided for floodways. In some SFHAs, floodways and mean floodway velocities have not been determined as part of the FIS.

The preferred scour mitigation technique is to place the manufactured home's foundation below the predicted ultimate scour depth. In areas where placing foundations below maximum scour depth is not economically feasible, alternative scour protection methods include reinforcing foundation soils with large diameter materials such as coarse aggregate or riprap.

5.2.6 Debris Impact Forces

Floodwaters can transport objects of all types (e.g., trees, portions of flood-damaged buildings, automobiles, boats, storage tanks, manufactured homes, etc.). In cold climates, winter floods can also carry large pieces of ice. Substances such as dirt, oil, gasoline, sewage, and various types of debris add to the dangers of flooding. Even when flow velocity is relatively low, large objects carried by floodwaters can easily damage windows, doors, walls, and, more importantly, critical structural components. As the flood velocity increases, the danger of damage from floodborne debris also increases.

Waterborne debris impacts caused significant damage to buildings and enclosures, slabs, decks, utilities, and other ancillary features when Hurricane Ivan struck the Florida panhandle and coastal Baldwin County, Alabama in 2004. Manufactured homes typically are not designed to withstand loads to walls or floor systems that may be exerted by attached carports, decks, porches, or awnings, although some manufacturers have designed homes that are "awning ready" to provide a load path through the structure to handle the increased stresses. The alternative is to build the attachments with adequately anchored foundations to resist these debris impact forces.

Damages caused by floodborne debris impacting a manufactured home depend not only on the weight and velocity of the debris, but also on the size and material. Historically, the forces developed when floating debris hits a home have been estimated using the principles of conservation of momentum with impact duration of 1 second. Recent research, however, indicates that the impact from floodborne debris occurs over intervals of only 0.01 to 0.05 second. Since impact force is inversely proportional to duration (i.e., the shorter the duration, the larger the impact force), historical methods may underestimate impact forces. Typical impact duration ranges from 0.1 second for stiff foundations (such as concrete) to 1 second for flexible foundations (such as wood).

$$F_i = (W/g) \times (V_b/t)$$

Where: F_i = impact force (pounds)

W = weight of floodborne object (pounds)

V_b = velocity of object (fps)

t = time for object to decelerate from V_b to zero (seconds)

g = acceleration due to gravity (32.2 ft/s^2)

ASCE 7-05 updates the methods of calculating impact debris forces. Recent research indicates that the impact durations are much shorter and impact loads are significantly higher than previously recommended. Foundations for manufactured homes located in SFHAs should be designed to resist floodborne debris impact forces calculated based on the most recent edition of ASCE 7 protocols.

The relatively light and frequently unreinforced foundation systems used to support and anchor manufactured homes are susceptible to impact damage from floating debris. The cost to strengthen foundations, ground anchors, and anchor straps to resist debris impact may be economically impractical. An alternative method is to install additional foundation elements to provide redundancy in the system. For example, reducing the frame span length by reducing pier spacing allows the frame to span across a damaged pier without excessive deflections or failure. This method requires post-flood inspection and maintenance to repair or replace damaged foundation elements to allow the home's foundation to survive any subsequent events. Also, if more foundation elements than what have been assumed are damaged, a finite risk of system failure remains.

5.3 Wind

Design and installation of foundations of manufactured homes is a controlling factor on the homes' ability to withstand forces from wind events. Connections used to secure the manufactured homes to the foundations have historically lacked the attention given to the manufacturing of the homes themselves. Lack of proper connections has caused numerous homes to fail during high-wind events. Figures 5-8 and 5-9 are examples of wind damage to modular and manufactured homes.

Several factors influence the direction and magnitude of wind forces on a structure, which should be considered in manufactured home foundation design.

When a structure is exposed to these wind forces in combination with flood forces, the damage potential is greatly increased.

Figure 5-8. Failure of a modular home due to high winds. The home lifted off of its foundation (concrete slab) when the connections failed.

Figure 5-9. A manufactured home that failed during a high-wind event.

5.3.1 Wind Forces on Structures

The texture and roughness of the terrain, as well as its surface contours and topography, have a profound effect on the wind loads. A structure in an open flat area with few trees and obstructions is likely to see a substantially higher wind load than one situated in a developed area with numerous buildings or other obstructions. Similarly, a structure situated on a hilltop may be subjected to significantly greater loads than one on flat terrain. All structures should be built to withstand the forces caused by the strongest wind speeds likely to happen at the site.

The basic design wind speeds for the United States can be obtained from the map given in Figure 6-1 of ASCE 7. The wind speeds correspond to 3-second gust speeds in mph at 33 feet (10 meters) above the ground for open terrain with scattered obstructions having heights generally less than 30 feet (9.1 meters), Exposure C category. This includes flat open country and grasslands.

When a building is exposed to wind, the wind flows over and around the building. This imposes positive pressure on the windward side of the building and negative pressure (suction) on the leeward side and roof of the building.

5.3.2 Wind Forces in Combination with Flood Forces

Damage potential is increased when wind forces are exerted on a structure in combination with flood forces, as is often the case in coastal and mountainous areas. For example, tensile forces can develop at the windward piers and the home can be lifted. If the windward piers are exposed to moving floodwaters, they can topple when no longer in contact with the home's steel frame.

Elevating a manufactured home to minimize the effects of flood forces does not significantly increase the wind loads on the home.

The HUD *Model Manufactured Home Installation Standards* require foundations to consider flood and wind load combinations. Sections 2.3.3 and 2.4.2 in Chapter 2 of ASCE 7, *Minimum Design Loads for Buildings and Other Structures* contain load combinations that should be used.

5.4 Earthquakes

Designing resistance of structures and foundations for earthquakes requires a different approach than that used for flooding and wind. Because earthquakes can affect internal building elements without requiring penetration of the building like flooding or wind, there are design considerations specific to earthquakes.

Often designing for wind load standards will allow a manufactured home installation to be adequate for protecting the home from earthquake forces. However, there are instances when forces resulting from earthquakes can result in greater loads than those for wind.

5.4.1 Design Philosophy

Earthquake-caused ground accelerations cause forces on building elements attached to or into the ground. Foundation movements are transmitted to structural and non-structural components. Consequently, exterior and interior building components should be designed for seismic loads to be transferred to the remaining elements.

In the event of an earthquake, a structure will be simultaneously subjected to vertical and horizontal accelerations. The weight of a manufactured home on its foundation is not sufficient to resist a moderate or severe earthquake. Therefore, the manufactured home and its foundation should be properly connected to avoid damage during an earthquake event. Soil liquefaction resulting from an earthquake is also an important consideration for earthquake design because soil liquefaction is a major cause of damage in a seismic event. Refer to Chapter 6 for a discussion on liquefaction.

5.4.2 Design Standard

Regulations governing the construction and design of manufactured homes currently do not specifically address seismic loads but rather specify loading requirements primarily to provide basic wind resistance. However, seismic requirements exist in most model codes and standards. Seismic requirements have been included in the *Model Manufactured Home Installation Guide* (NFPA 225).

Historically, communities with low seismicity have considered wind load provisions as sufficient for resisting seismic events. Although this may be true in the case of transverse loading (i.e., wind pressures acting on the long walls) where wind loads are high, it is often not the case with longitudinal loading where wind loads are low. Also, the nature of seismic loading is greatly different than wind loading. These differences make comparisons between wind resistance and seismic resistance tenuous at best.

Studies list the following typical damages to manufactured homes during design earthquakes:

- Homes falling off support systems
- Damage to floors from piers puncturing them
- Disruption of gas, water, and electrical lines from seismic motions of the home
- Fire resulting from damaged water heaters, and gas and electric lines. (A simple and cost-effective seismic mitigation measure for manufactured homes is to strap the water heater to a wall to prevent it from falling over.)

For a manufactured home installed on a foundation system, providing adequate resistance to lateral movement, uplift, and rotation is very important. It is also necessary to provide tensile connections between the main frame and the piers supporting the home to resist all seismic forces. Earthquake-resistant bracing systems (ERBSs) can be installed to minimize damage to the home, but they do not provide the protection of a seismic-resistant foundation system. ERBSs are secondary supports that do not resist seismic forces, but rather allow the home to fall from its primary supports and "catch" it before it hits the ground.

The State of California has had an ERBS certification program since 1987. To be certified, the ERBS must be able to limit seismic movement and limit vertical drop of the manufactured home to 2 inches. A list of certified ERBSs is available from the State of California, Department of Housing and Community Development, Division of Codes and Standards. The price range of ERBSs is from approximately $2,000 up to $5,000; the average cost of an ERBS is about $2,500. The State of California also permits the use of other systems that do not require the home to fall off supports, as is the case with ERBSs.

5.5 Evaluation of Multi-Hazards

Manufactured homes, like all buildings, can be simultaneously subjected to many natural hazards, and the combined effects of the forces generated from these hazards must be considered. The different loads that must be considered in the design of a manufactured home foundation are shown in Table 5-2.

Table 5-2. Load Combination Nomenclature (ASCE 7)

Nomenclature	Load Description
D	Dead load
L	Live load
F	I l ^a a r b q l « r f a t f q e t b i i * a b ª k b a m o b p p r o b p ^k a j ^u f j r j e b f d e q p
F_a	Flood loads
H	Load due to lateral earth pressure, groundwater pressure, or pressure of bulk materials
T	Self-straining force

Table 5-2. Load Combination Nomenclature (ASCE 7) (continued)

Nomenclature	Load Description
L_r	Roof live load
S	Snow load
R	Rain load
W	Wind load
E	Earthquake load

Load combinations are used in the design process to take into account the simultaneous occurrence of different hazards. Manufactured homes and their foundations should be designed to the load combinations indicated by the applicable building code for the area. In the absence of a building code, the manufactured home should be designed in accordance with the load combinations given in ASCE 7.

5.5.1 Load Combinations (ASCE 7)

5.5.1.1 Strength Design (Load and Resistance Factor Design)

Strength design is defined as a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not exceed the member design strength.

According to ASCE 7, the basic load combinations for strength design (using the nomenclature in Table 5-2) are as follows:

1. 1.4(D+F)
2. 1.2(D+F+T) + 1.6(L+H) + 0.5(L_r or S or R)
3. 1.2D + 1.6(L_r or S or R) + (L or 0.8W)
4. 1.2D + 1.6W + L + 0.5(L_r or S or R)
5. 1.2D + 1.0E + L + 0.2S
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

When a structure is located in a flood zone, the following load combinations must also be considered:

1. In V zones or Coastal A zones, 1.6W in combinations (4) and (6) shall be replaced with 1.6W + 2.0F_a.

2. In non-Coastal A zones, 1.6W in combinations (4) and (6) shall be replaced by 0.8W + $1.0F_a$.

5.5.1.2 Allowable Stress Design (also known as Working Stress Design)

Allowable stress design (ASD) is defined as a method of proportioning structural members such that computed stresses produced in the members by nominal loads do not exceed specified allowable stresses.

According to ASCE 7, the basic load combinations for ASD are as follows:

1. D + F
2. D + H + F + L + T
3. D + H + F + (L_r or S or R)
4. D + H + F + 0.75(L + T) + 0.75(L_r or S or R)
5. D + H + F + (W or 0.75E)
6. D + H + F + 0.75(W or 0.7E) + 0.75L + 0.75(L_r or S or R)
7. 0.6D + W + H
8. 0.6D + 0.7E + H

When a structure is located in a flood zone, the following load combinations must be considered:

1. In V zones or Coastal A zones, 1.5 F_a shall be added to other loads in combinations 5, 6, and 7 and E shall be set equal to zero in 5 and 6.
2. In non-Coastal A zones, $0.75F_a$ shall be added to combinations 5, 6, and 7 and E shall be set equal to zero in 5 and 6.

Either ASD or strength-based design can be used for manufactured housing. In both design methods, wind and seismic loads need to be evaluated. In addition, increases in allowable stress shall be used with these load combinations where allowed by the locally adopted building code.

6 Soils

Soil properties can significantly impact manufactured homes exposed to flooding. Properly determining soil type and allowable bearing capacity is important for the selection and performance of the foundation. It is recommended that a geotechnical engineer make these determinations. For example, highly erodible soils are not desirable as fill for elevating a structure in a high velocity area because it can be washed away by moving floodwaters. Other soils lose strength as moisture content increases, reducing a foundation's load capacity. This chapter discusses the effect of flooding on soil properties.

6.1 Bearing Capacity

Bearing capacity is a soil's capability to support load without catastrophic failure. Bearing capacity is derived from the soil shear strength, which is expressed as:

$$s = c + \rho \ (\tan \phi)$$

Where s = soil shear strength

c = soil cohesive strength

ρ = lateral confining pressure

ϕ = soil angle of internal friction

The general bearing capacity equation is:

$$q = (\gamma b/2)N_{\gamma} + cN_{c} + \rho N_{\rho}$$

Where q = soil bearing capacity

γ = unit weight of soil

b = footing width

N_{γ} = bearing capacity factor for soil density and footing size

N_{c} = bearing capacity factor for cohesion

N_{ρ} = bearing capacity factor for surcharge

As previously discussed, soil strength frequently changes as a function of moisture content. In granular soils, as moisture content approaches saturation (i.e., intergranular voids are 100 percent filled with water), the effective unit weight is reduced, thus reducing the confining pressure (ρ).

For preliminary design purposes, allowable bearing capacities can be established based on national model codes, local building codes, and soil surveys. Local officials may also have information on soil types and soil bearing capacities.

Soil classifications of a general nature and a typical range of their maximum allowable bearing capacities can be found in publications such as the IBC (2009 Edition), NFPA 5000 (2009 Edition), and NFPA 225 (2009 Edition). These documents can provide the allowable bearing pressures considered sufficient to support foundations at well drained sites. Excessive foundation movement or settlement may occur where unusual soil or moisture conditions are encountered. A geotechnical engineer should be consulted when unusual soil or moisture conditions are present.

6.2 Effects of Flood Duration and Frequency on Soil

For granular soils located below the water surface, the effective confining pressure (ρ') is used to determine the effective shear strength'. The effective confining pressure is calculated using the effective unit weight of the soil where:

$\gamma' = \gamma_s - \gamma_w$

γ' = effective unit weight of soil

γ_s = total unit weight of soil and

γ_w = unit weight of water

The submerged weight can be estimated as about half of the total weight of many granular soils. The angle of internal friction (ϕ) is not appreciably changed by submergence. Therefore, if the water table rises from a depth greater than the width of the footing to the ground surface, as can be the case of flooding, the bearing capacity of the soil is reduced by approximately 50 percent.

Cohesive soils (silt and clay) are bound together by electrochemical bonds between individual particles. Increasing the moisture content can change the distance between particles, decreasing the strength of the inter-particle bonds. The decrease in bond strength results in a decrease in cohesion and a loss of shear strength.

6.3 Soil Liquefaction

Seismic soil liquefaction is an important consideration for earthquake design because soil liquefaction can be a major cause of damage in a seismic event. Liquefaction is defined as the significant loss of strength resulting from an increase in soil pore pressure. Seismic vibrations act to realign soil particles into a denser configuration. The realignment decreases the inter-particle void space, thus increasing the water pressure in the voids. The increase in water pressure

has the effect of decreasing the effective strength of the soil. A sufficient increase in pore pressure can reduce the effective strength to zero, at which time the soil mass behaves as a liquid. The loss of shear strength in soils supporting buildings can be catastrophic. Building foundations can slide or unevenly settle, bridges can collapse, and empty fuel tanks buried under ground can rise to the surface.

Liquefaction-induced soil movements can push foundations out of place to the point where the manufactured home will lose support.

Loose clean sands with relatively few fines, and silty soils with little or no clay, are vulnerable to seismic induced liquefaction. It is necessary to identify the presence of liquefaction susceptible soils expected to support building foundations, and design the manufactured home foundation accordingly.

To reduce liquefaction hazards, the best approach is to avoid construction on soils susceptible to liquefaction. Other options such as making the structure liquefaction resistant or improving the strength, density, and/or drainage characteristics of the soil are probably not economical for most manufactured home sites.

6.4 Recommended Soil Testing and Criteria for Manufactured Home Installations

Shallow subsurface investigations should be conducted to evaluate the soil bearing conditions at the proposed manufactured home site. An experienced geotechnical engineer can conduct an appropriate investigation using hand augers, field strength tests, and visual classification methods. Field strength testing includes dynamic cone penetration tests, pocket penetrometer tests for cohesive soils, and torvane tests for granular soils. The investigation should evaluate soils to a depth of twice the width of the bearing surface or 5 feet, whichever is greater. The investigation will provide information on soil type and bearing capacity.

When footings are eccentrically loaded, the effective bearing area is reduced so footing sizes must be increased accordingly. Eccentric loading occurs when piers are not centered over footings and when a manufactured home frame is not centered on its pier. Eccentrically loaded foundation conditions should be avoided.

Ground anchors consist of a specific anchoring device designed to transfer home anchoring loads to the ground (24 CFR 3285.5). Axially loaded ground anchors support loads by mobilizing soil shear strength along a subsurface shear plane. Ground anchors loaded non-axially resist loads through both the axial shear strength and passive soil resistance against the horizontal component of the non-axial load. Development of passive soil resistance requires some soil movement. The required movement will generally result in larger total movement in non-axially loaded anchors than axially loaded anchors in the same soil conditions.

7 Ground Anchors

Both the NFIP regulations (44 CFR 60.3) and the HUD *Model Manufactured Home Installation Standards* (24 CFR 3285.305) require that manufactured homes installed in flood-prone or SFHAs be anchored to resist flotation, collapse, or lateral movement.[1]

Ground anchors consist of a specific anchoring assembly designed to transfer home anchoring loads to the ground (24 CFR 3285.5). They are used extensively in manufactured home installations. Ground anchors are economical, readily available, and can be installed with relatively lightweight tools and equipment.

Ground anchors have potential limitations. One significant limitation arises from multiple soil-anchor response mechanisms as a function of soil type, anchor depth, and load configuration. Ground anchors have historically been allowed to move up to 3 inches horizontally or 2 inches vertically as the basis for determining acceptable performance. (Appendix E of the IRC established a ground anchor moving 2 inches in the direction of pull of the load as being acceptable.) When a manufactured home is secured with ground anchors, it too can move up to 3 inches when exposed to flood, wind, or seismic events.

Three inches of horizontal movement can produce eccentrically applied loads on piers under a home, which can cause the piers to topple and the home to collapse. Two inches of vertical movement can allow the home to lift and lose contact with the supporting piers. Unless the home is securely fastened to the piers and the piers constructed as monolithic units, the loss of contact can make the piers vulnerable to being displaced by moving floodwaters.

Ground anchor movements of several inches can have significant negative impacts on long-term performance. In cohesive soils, such anchor movements in a vertical direction can approach or exceed the soil's shear strength. In such cases, the ground anchor is supported by the soil's residual shear strength, resulting in a decrease in anchor capacity. In granular soils, large lateral movements may produce failure planes that can reduce the strength on the vertical direction.

Anchor assemblies, including ground anchors, should be inspected periodically, especially after hazard events. Loose anchor straps need to be retightened, and loose or failed anchors need to be reset or replaced. If movement has made the manufactured home structurally unstable, it should be reset to center it on its supporting piers. If this maintenance is not performed, the anchor assembly may fail during subsequent hazard events, resulting in significant damage to or destruction of the home. Tightening ground anchor straps typically costs a few hundred dollars or less. Replacing anchors or resetting a home is estimated to cost at least $1,000.

1 44 CFR 60.3(a), 44 CFR 60.3(b), and 24 CFR 3285.305 use the phrase "flotation, collapse or lateral movement." 44C FR 60.3(c) uses the phrase "flotation, collapse and lateral movement." To account for both usages, this publication uses "or."

7.1 Types of Anchors and Installed Configurations

7.1.1 Types of Anchors

Several styles of anchor assemblies are available that can adequately secure a manufactured home to resist flood, wind, and seismic forces. Helical earth anchors, cast-in-place concrete footings, drilled concrete anchors, and cross drive anchors are just a few of the types available.

7.1.1.1 Helical Earth Anchors

Helical earth anchors are designed to be augured (screwed) into the ground and are often referred to as ground anchors. Helical earth anchors typically consist of a shaft, head, and one or more helixes. The head is used for installing and fastening the anchor to the home, and tensioning the anchor. Toward the bottom of the shaft, there is one (single) or more helical disks for the anchor to be screwed into the soil. The helix provides much of the anchor's load capacity. The typical lengths of helical ground anchors are 30, 36, 48, and 60 inches.

Helical anchors also may be installed with stabilizer plates to increase the lateral capacity of the anchor by enlarging the surface area used to develop passive soil resistance.

7.1.1.2 Concrete Anchors

Concrete anchors use dead weight of a concrete footing or a combination of concrete weight and soil uplift resistance. Uplift resistance can be increased by the use of drilled concrete piers. In both cases, the home must be securely attached to the concrete elements using anchor bolts, tie-rods, or other structural connection. Anchor attachments placed in concrete must be installed with adequate depth to develop the required strength. The load capacity of the anchors must be sufficient to resist applicable design loads.

7.1.1.3 Cross Drive Anchors

Like helical ground anchors, cross drive anchors are constructed with a head secured to a metal shaft. Cross drive anchors are shafts driven into competent soils to develop their resistance. As their name implies, cross drive anchors are driven in pairs that form an "X" or cross (Figure 7-1). The heads of the anchors are secured to the home with metal straps.

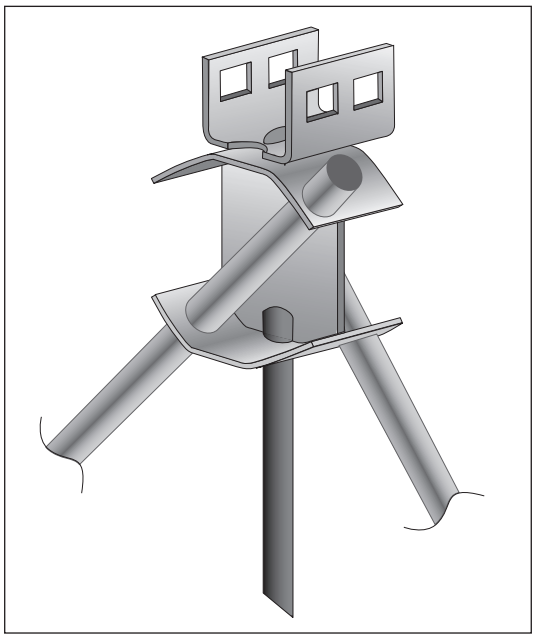


Figure 7-1. Cross drive anchor. (Courtesy of Tie Down Engineering)

7.1.2 Anchor Construction and Capacity

Steel ground anchors are the most common anchor assembly application for manufactured home installations. Ground anchors are typically constructed with a circular shaft of one or more helixes; a head connects at the opposite end of the anchor, which then connects to the home's frame and/or sidewalls with steel straps or cables. Anchor shafts are typically 5/8 inch to 3/4 inch in diameter, and helixes range from 3 inches to 8 inches in diameter. Most anchors used for manufactured home applications have one helix, although anchors with two to four helixes are available (Figure 7-2).

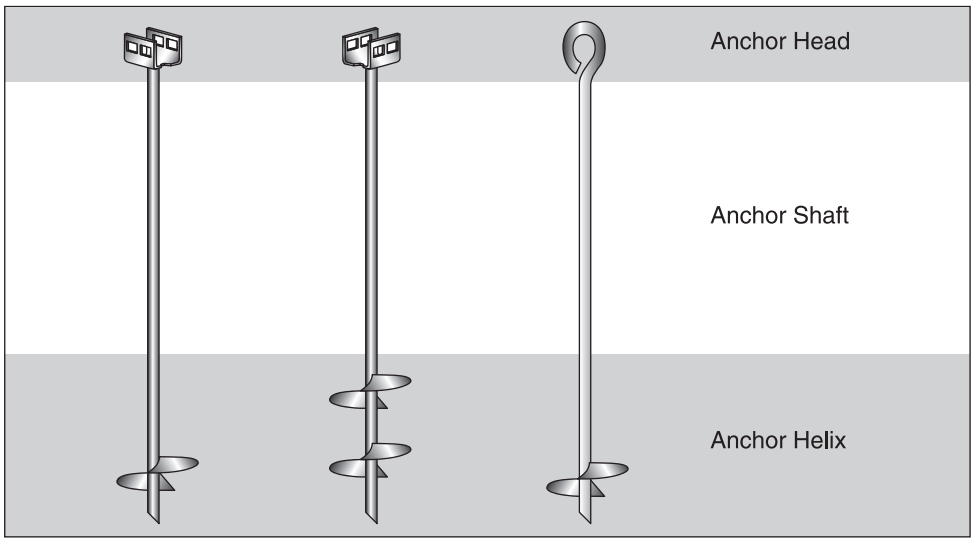


Figure 7-2. Single and double helix ground anchors with strap connection and single helix anchor with a closed-eye connection.

Most anchor heads are "U" shaped and contain predrilled bolt holes. The bolts connect the anchor to the home's frame or sidewalls with 1¼-inch anchor straps. Some anchors have heads with closed eyes for cable connections. The bolts in "U" shaped anchor heads can be used to pre-tension the anchor. Pre-tensioning an anchor with closed-eye heads requires using other devices like turnbuckles.

HUD requires anchoring equipment and anchoring assemblies to be capable of resisting allowable minimum working loads of 3,150 pounds and ultimate loads of 4,725 pounds without failure of either the anchoring equipment or the attachment point on the manufactured home.

7.1.3 Anchor Selection

Ground anchors should be selected based on the specific soils conditions at the manufactured home site. Short anchors with smaller helixes may be used in firm, well compacted soils. Longer anchors or anchors with larger or multiple helixes are required in weaker soils.

Most anchors are selected based on standard torque probe tests conducted at the site. During those tests, a 5-foot long auger probe is screwed into the ground to the approximate depth of the anchor helix. A torque wrench measures the torque required to advance the probe. The resulting torque value is used to classify the soils and select an appropriate anchor based on

recommendations of the anchor manufacturers. Table 7-1 depicts how one anchor manufacturer classifies soils for anchor selection.

Table 7-1. Soil Classifications Using a Standard Torque Probe (STP)

Soil Class	Test Value (in. lbs.)	Soil Description
1	N/A	Sound hard rock.
2	550+	Very dense and/or cemented sands, coarse gravel, cobbles, preloaded silts, clays, and coral.
3	350 to 550	Medium dense coarse sands, sandy gravels, very stiff silts and clays.
4a	275 to 350	Loose to medium dense sands, firm to stiff clays and silts, alluvial fill.
4b	175* to 275	Loose sands, firm clays and silts, alluvial fill.
	*Below 175 in. lbs. a professional engineer should be consulted	

7.1.4 Anchor Installation

Anchors can be machine-installed or hand-installed. Machine installation involves using portable torque equipment to rotate and advance the anchors into the supporting soils. Figure 7-3 shows an electric installation device, also known as a portable anchor drive machine.

Figure 7-3. Electric anchor drive machine. (Courtesy of Tie Down Engineering)

Hand installation involves excavating holes for the anchors, placing the anchors into the holes, and then backfilling and compacting the removed soil. Hand installation disturbs significantly more soil than machine installation and reduces anchor load capacity. Manufacturers typically limit the depth of pre-drilling to two-thirds the anchor length. They also recommend against hand installations in areas with poor soils.

Anchors are typically installed vertically or inclined slightly from vertical to facilitate installation. Typical inclinations range from approximately 5 to 15 degrees from vertical. Where required, stabilizer plates are installed adjacent to the anchor shaft (Figure 7-4). This allows anchors to

be installed after the manufactured home is positioned and locates the exposed anchor heads behind the manufactured home's skirting. Anchor straps are then installed to the manufactured home frames and, in HUD Wind Zones II and III, to the wall ties installed when the home is fabricated. When used in this configuration, stabilizer plates are installed to provide additional lateral resistance for the anchor assembly.

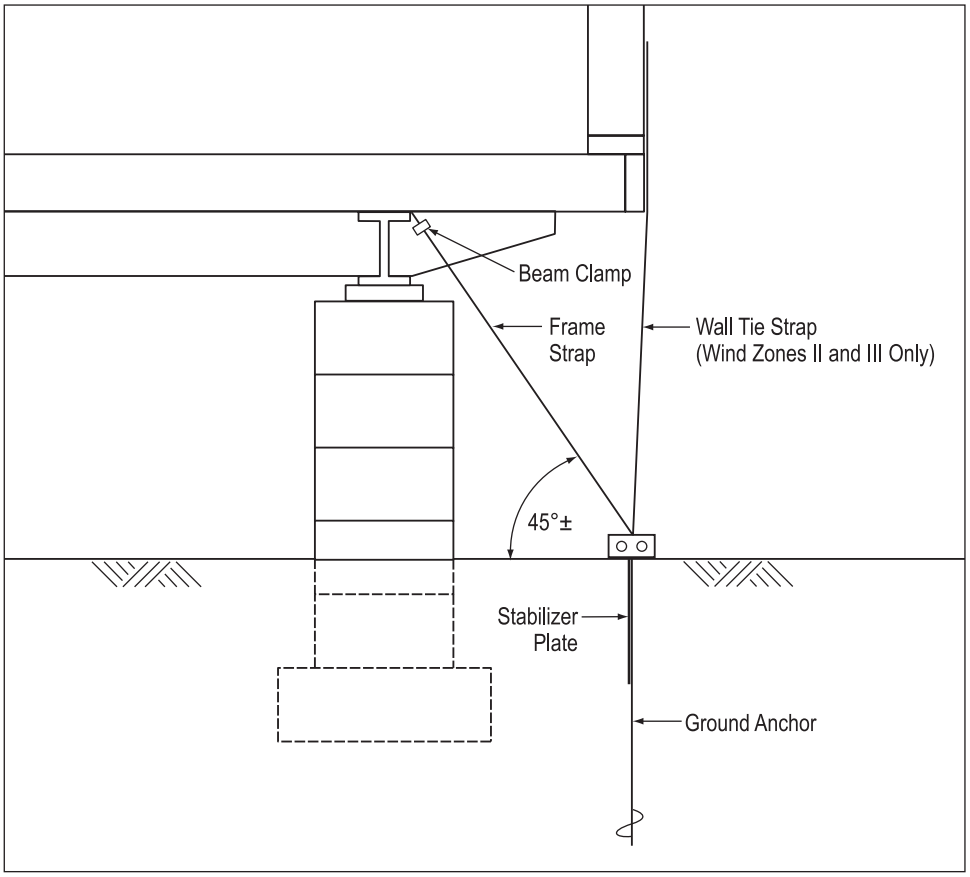


Figure 7-4. Typical ground anchor installation.

When fastened as vertical wall ties and loaded axially, ground anchors may be used without stabilizer plates. When ground anchors are used with some proprietary foundation systems, anchors can be installed 45 degrees to the horizontal and loaded axially (Figure 7-5).

7.1.5 Anchor Performance

The capacity of anchoring systems is a function of the soil response to loads applied to the anchor assembly. For ground anchors, important geotechnical considerations include soil type or classification, soil shear strength, load-deformation characteristics (i.e., modulus of subgrade reaction, or stiffness), and moisture condition. Research has identified additional considerations impacting the capacity and performance of ground anchors, including anchor geometry, anchor depth, anchor orientation, and direction of load relative to that orientation.

Soil response mechanisms are different for axially and non-axially loaded ground anchors. Soil response for axially loaded ground anchors is the result of shear stresses along the failure plane.

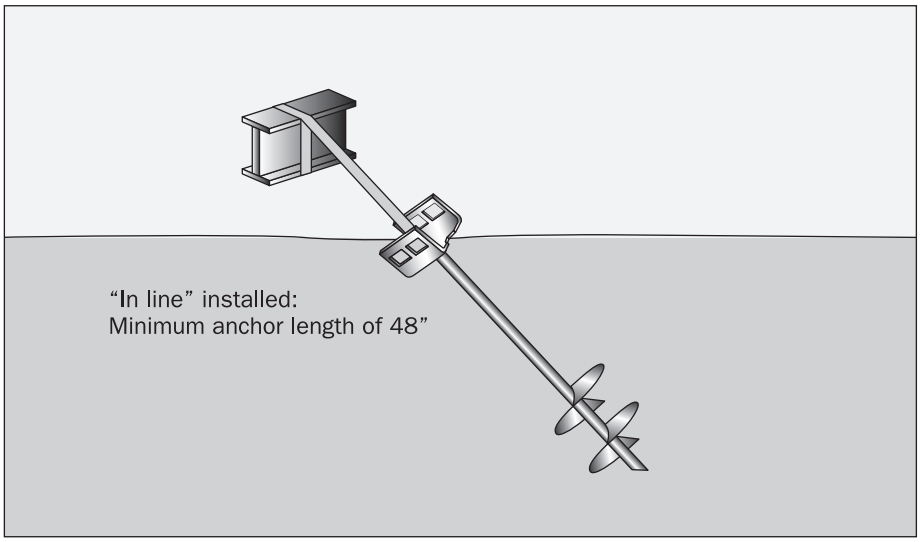


Figure 7-5. In line ground anchor installation.

Failure occurs when the stresses exceed the soil shear strength. The geometry of the failure surface varies based on the critical depth of the anchor. Ground anchors with an embedment depth less than the critical depth to anchor base width ratio ($(D/B)_{cr}$) respond as a shallow foundation. Ground anchors with a depth greater than $(D/B)_{cr}$ respond as a deep foundation.

Non-axially loaded ground anchors resist lateral movement by mobilizing the passive resistance of the surrounding soil. As small diameter rods develop little passive soil pressure resistance, stabilizer plates are used in the contact area to increase the passive resistance and reduce movement.

Figure 7-6 plots anchor load (in pounds) as a function of anchor head displacement (in inches), and shows the typical response for an anchor installed vertically and loaded axially. A test load of 6,000 pounds resulted in a movement of less than 2 inches. The graph also indicates that little or no movement occurred at loads less than about 225 pounds.

Vertical, axially loaded anchors are relatively efficient. The soil shear failure is a symmetrical, roughly truncated cone extended from the anchor bearing plate to the ground surface. Non-vertical, axially loaded ground anchors are somewhat less efficient due to the asymmetrical shape of the shear failure surface. The asymmetry is the result of the shallow depth at the top side of the anchor relative to the bottom side.

Movements of axially loaded anchors are proportional to the applied loads. The load-movement is approximately linear in granular or non-cohesive soils. Cohesive soils tend to be less linear, particularly as the amount of clay in the soil increases. Soil related anchor failure in granular soils may occur rapidly and may cause ground surface movements around the anchor. Anchors in cohesive soil typically fail more slowly.

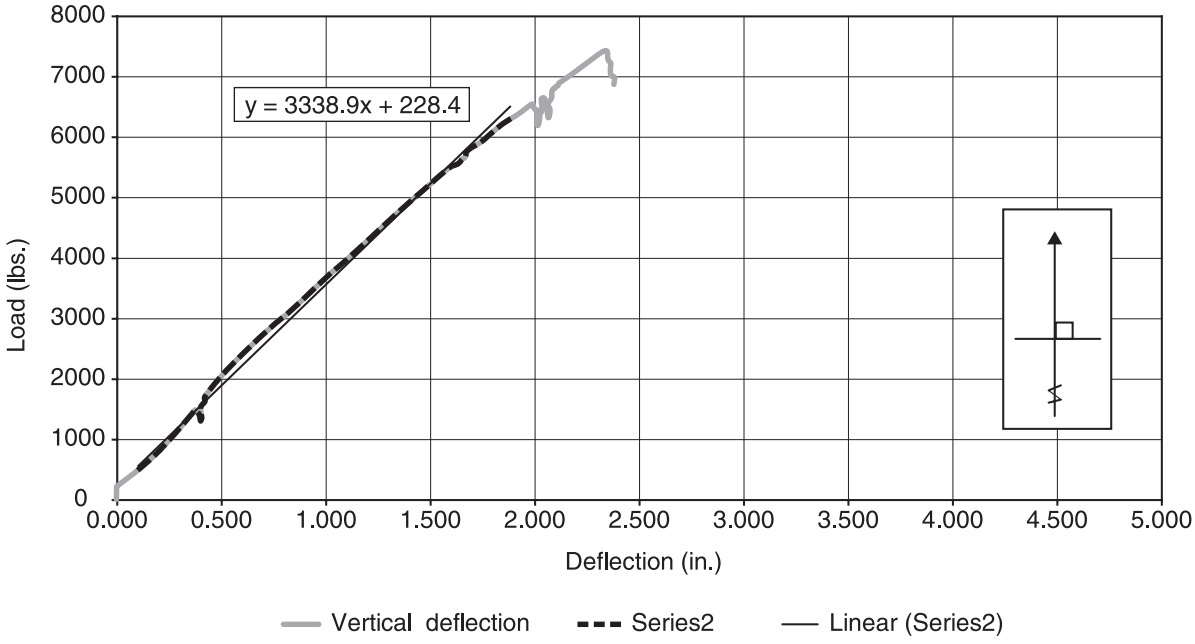


Figure 7-6. Typical response for an axially loaded anchor.

Anchor failure may also result from weld failure between the anchor shaft and the anchor head, weld failure between the shaft and the helix, collapsing of the anchor helix, or metal tearing around the anchor head strap bolts.

Anchors used with stabilizer plates respond differently than axially loaded anchors. Figure 7-7 shows the typical response for non-axially loaded anchors used with stabilizer plates. The small diameter shaft does not create much passive resistance in the soil; therefore, small loads produce relatively large movements. After the anchor shaft contacts the stabilizer plate, lateral movement as a function of load decreases significantly as a result of a larger area of passive resistance mobilized by the stabilizer plate. After the shaft contacts the stabilizer plate, stiffness, as indicated by the slope of the load vs. movement curve, increases significantly. However, the apparent stiffness, as indicated by the slope of the curve, remains less than axially loaded anchors.

For both axially and non-axially loaded anchors, the design stiffness should be selected to account for the variability of individual anchor performance during anchor tests, including an assessment of the upper limit of the applicability of the stiffness factor.

Shear strength in saturated soil is typically less than in non-saturated soils. Thus, anchors in saturated soils have a lower load capacity than non-saturated soils, and may exhibit decreased stiffness, especially in clays.

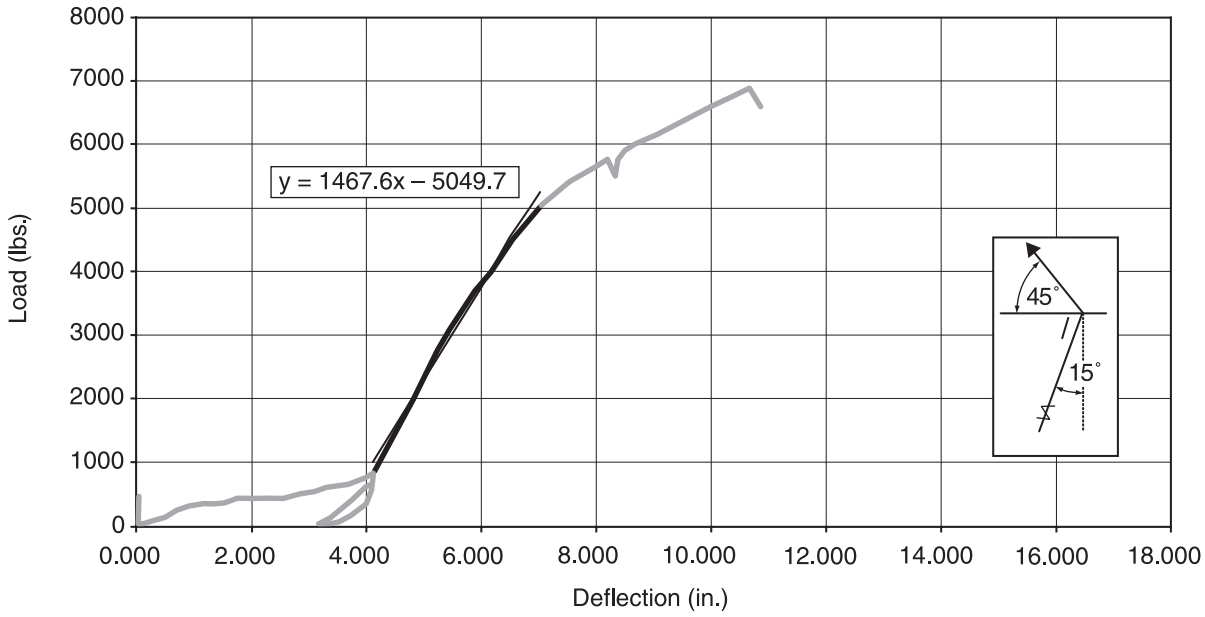


Figure 7-7. Typical response for a non-axially loaded anchor used with a stabilizer plate.

7.1.6 Anchors and Other Foundation Elements

Ground anchors are used with masonry piers, wood posts, or steel jack stands. For satisfactory performance, the piers, posts, and stands must function with relatively large displacements that the anchors may experience when subjected to flood, high-wind, or seismic loads. Large displacements are especially likely for non-axially loaded ground anchors. If subjected to relatively large movements, many foundation components cannot maintain their integrity. Piers, for example, can experience failure due to sliding of unmortared blocks or overturning of reinforced piers supported on ground surface pads (Figure 7-8).

7.2 FEMA Anchor Test Program

7.2.1 Anchors in Saturated Soils

Flooding can decrease soil shear strength and change the subsurface hydrostatic pressures as a result of an increase in the pressure gradient. The two mechanisms affect ground anchor performance differently. The effects are a function of soil characteristics, anchor end plate diameter, installation depth, and change in hydrostatic pressure. Research has indicated that, for a fixed depth, the ultimate capacity of screw anchors in dry sand is higher than screw anchors in submerged conditions. The impact of the reduction in capacity is significantly greater for shallow anchors than for deep anchors.

In 2002, FEMA participated in a field test program of 120 anchors to provide performance data for developing pre-engineered foundation designs using ground anchors. Sixty anchors were tested in a saturated site, and 60 anchors were tested in an adjacent dry site as a control group.

Figure 7-8. Failed foundation system that used masonry piers.

The results generally support the findings of previous research and have been used to develop the foundation designs included in this guide.

The tests were conducted by representatives from FEMA and its engineering consultants, HUD, the Manufactured Housing Institute (MHI), Florida Manufactured Housing Association (FMHA) and several ground anchor manufacturers (Tie Down Engineering, Oliver Technologies, Minute-Man, and Style Crest).

7.2.2 Anchor Test Results

Tables 7-2 and 7-3 contain the test results for dry site anchors and wet site anchors, respectively. Figure 7-9 shows three anchor configurations described in Tables 7-2 and 7-3. The data shown are for anchor stiffness or the amount of load the anchors develop per inch of anchor head movement. The data are raw data and are not indicative of design or working load values.

The data also include the standard deviations for the data groups. The data show that the performance of individual ground anchors varies significantly from the average performance of the group of anchors. This variance, or "spread" in ground anchor performance has a significant effect on appropriate design values. The greater the relative spread in individual anchor performance, the lower the appropriate design value.

Table 7-2. Dry Site Anchor Data

Anchor Style and Installation	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	1,505	3,283	2,426	543
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	1,774	6,639	3,801	1,394
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,006	2,001	1,475	294
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch acrylonitrile butadiene styrene (ABS) stabilizer plate (Figure 7-9b)	1,019	2,612	1,721	497
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	817	1,614	1,197	257

Table 7-3. Wet Site Anchor Data

Anchor Style and Installation*	Anchor Stiffness (pound/inch)			
	Min	Max	Average	Standard Deviation
5-foot anchor installed at 45° and loaded axially (Figure 7-9a)	2,874	9,019	5,506	1,829
5-foot anchor installed vertically and loaded axially (Figure 7-9c)	2,166	6,581	4,112	1,391
5-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	833	1,412	1,094	193
4-foot anchor installed 15° from vertical and used with an 8-inch by 24-inch ABS stabilizer plate (Figure 7-9b)	655	2,006	1,538	370
4-foot anchor installed 15° from vertical and used with an 11-inch by 17-inch stabilizer plate (Figure 7-9b)	1,024	1,894	1,319	300

* See Figure 7-9.

Note that anchor stiffness values are based on the linear portion of the load deflection data. In most cases, the non-axially loaded anchors' significant movements occurred prior to reaching the linear response range. It should also be noted that the upper and lower limits of applicability of the stiffness values have not been fully evaluated. For axially loaded anchors in dry sand, the linear zone appears to exceed 6,000 pounds, about the limit of the test. Vertically loaded vertical anchors in wet sand had similar results; however, axially loaded anchors installed at 45

degrees in wet sand had an upper limit of about 4,500 to 5,000 pounds. Similar differences were observed for inclined anchors.

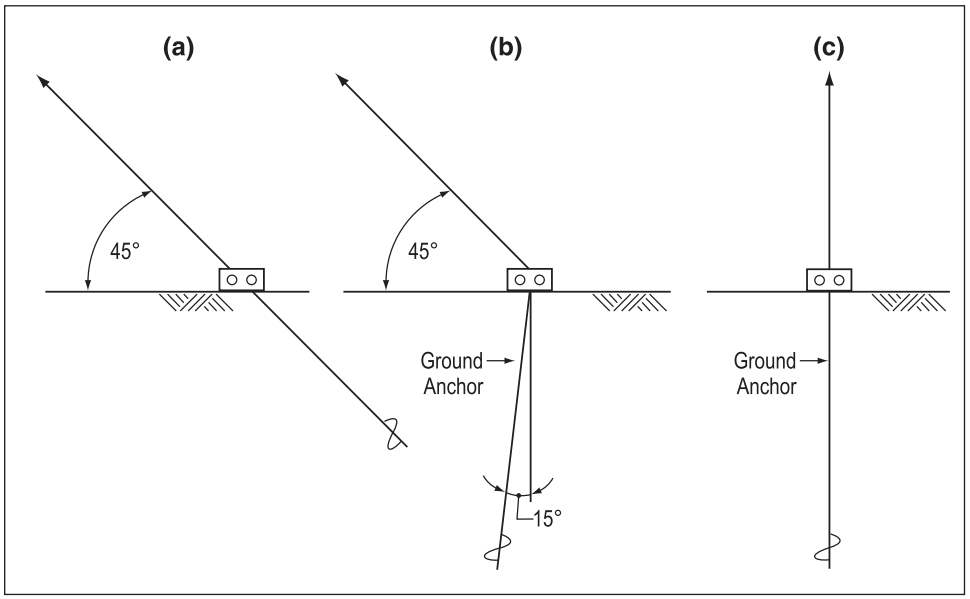


Figure 7-9. Three graphics showing the anchor configurations described in Tables 7-2 and 7-3. From left to right, they are (a) ground anchor installed at 45 degrees and loaded axially, (b) ground anchor installed at 15 degrees from vertical and loaded 45 degrees from horizontal, and (c) ground anchor installed vertically and loaded axially.

7.3 Recommended Ground Anchor Certification, Performance, and Design Values

7.3.1 Recommended Ground Anchor Certification Performance

Currently, there is no consensus based standard protocol for certifying ground anchors used to anchor manufactured homes. Some States have developed certification procedures and a task group under HUD's Manufactured Housing Consensus Committee (MHCC) has been working on a Ground Anchor Test Protocol (GATP) for certifying ground anchors. Although no standard protocol had been completed at the time this guide was published, the ground anchor design strengths included in this guide assume that the ground anchors will achieve a level of performance that can be relied upon to anchor the home and resist applied loads from a design event.

7.3.2 Recommended Ground Anchor Design Values

The following data present recommended ground anchor design values for use when ground anchors have not been load tested or otherwise certified for a specific capacity. The information, while limited, is based on the best available data from the FEMA ground anchor testing program. FEMA's testing program gathered data on ground anchor performance and soil saturation effects, and was conducted on sandy Class 4b soils.

The recommended design loads contained in Table 7-4 were developed by applying the statistical factors required to produce a design load that provides a 10 percent lower exclusion limit with a 90 percent confidence level. The factors were applied to the FEMA test data.

Table 7-4. Recommended Design Loads – from FEMA Ground Anchor Testing Program

Anchor Style and Installation – FEMA Tests	Recommended Design Load (pounds)
5-foot anchor installed at 45°and loaded axially	3,150
5-foot anchor installed vertically and loaded axially	3,000
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	2,000
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	2,000

Recommended design stiffness values were selected that provide a 90 percent confidence level; this means that no more than 10 percent of individual anchors would provide resistances less than design values. This level of statistical performance is less conservative, but similar to statistical performance levels applied to other structural materials like steel or concrete.

The lowest stiffness values from the dry and wet sites were selected for design. Generally, the dry site values controlled for axial pull anchors while the saturated site anchor values controlled for anchors using stabilizer plates. Table 7-5 lists the recommended design stiffness for the anchors tested.

Table 7-5. Recommended Design Stiffness for Tested Anchors

Anchor Style and Installation	Anchor Design Stiffness (pound/inch)	Controlling Soils
5-foot anchor installed at 45° and loaded axially	1,200	dry
5-foot anchor installed vertically and loaded axially	1,010	dry
5-foot anchor used with an 11-inch by 17-inch stabilizer plate	675	wet
4-foot anchor with an 8-inch by 24-inch ABS stabilizer plate	708	wet
4-foot anchor used with an 11-inch by 17-inch stabilizer plate	659	wet

With a 3-inch displacement, the axially loaded anchors provide working loads greater than the 3,150-pound loads required by HUD (e.g., 1,200 pounds/inch x 3 inches = 3,600 pounds). However, the anchors with stabilizer plates provide only about two-thirds of the HUD required capacity. The anchor stiffness values in Table 7-5 are based on the linear portion of the load-deflection curve. Designers need to evaluate potential deflections at loads below the linear range, particularly for inclined anchors loaded non-axially.

7.4 Ground Anchors in Seismically Active Areas

While data exist on the performance of ground anchors in static saturated soils, no definitive testing has been completed that predicts how ground anchors will perform in saturated soils during a seismic event. Seismic events can result in soil liquefaction, particularly in fine sands like those in the test program. Liquefaction may result in a significant and potentially total loss of anchor capacity during a seismic event. A registered engineer should be consulted to evaluate the liquefaction potential at the proposed manufactured home installation site.

8 Foundation Systems

8.1 Introduction

Properly designed and constructed manufactured home foundations can significantly reduce the potential for damages from flooding, high winds, and seismic events. Many styles of foundations are available for supporting manufactured homes. Continuous perimeter walls, constructed of concrete, masonry, or treated wood; concrete or masonry piers; wood posts and piles; and systems consisting of piers and ground anchors are some of the options available to a manufactured homeowner and installer.

To be effective, manufactured home foundations must perform the following:

- Support the weight of the home, its contents, and its occupants
- Resist design loads from wind, snow, seismic events, and moving floodwaters
- Elevate the home sufficiently to prevent losses from a design flood event

Elevated foundations are classified as enclosed or open. As the name implies, enclosed foundations enclose the space below the elevated home. Perimeter masonry, concrete, or sheathed wood walls are enclosed styles. Open foundations consist of a system of individual members that support the home only at discrete locations. Pier, post, and pile foundation systems are open systems. Many open foundations have a non-structural skirting to enclose the space below the home. The skirting is primarily for aesthetics and does not add to the strength of the foundation. Skirting can help to protect piping installed below the home from freezing and reduce both heat loss from the home and the potential for animal or insect entry into the home.

Selecting an appropriate foundation system depends on a number of variables, including the building site conditions (elevation, slope, access restrictions, drainage); the flood zone; the design loads (wind, flood, snow, and, if appropriate, seismic) at the site; the availability of materials; on-site soil characteristics; local construction practices; and cost. Whatever foundation system is chosen, both the HUD Code and NFIP require a foundation to resist flotation, collapse, or lateral movement during a design event to prevent damages to the home and surrounding structures. Tables 8-1 through 8-3 at the conclusion of this chapter provide guidance to the selection of appropriate manufactured home foundation systems as a function of flood depth and flow velocity.

Proprietary systems are also an option for the manufactured homeowner. Proprietary systems are discussed in Section 2.2.2 and the system must meet the design and performance criteria described in Chapter 9.

More information on proprietary foundations is contained in the SBRA's *Guide to Foundation and Support Systems for Manufactured Homes* available at http://www.research-alliance.org/pages/foundations_guide.htm.

8.2 Enclosed Foundations

Enclosed foundations consist of perimeter foundation walls placed on continuous footings. The walls enclose the area below the living space of the home (Figure 8-1). Perimeter walls are commonly constructed of concrete, masonry, or wood. Enclosed foundations are occasionally used to raise manufactured homes, often creating the appearance of a site-built home (Figure 8-1).

Figure 8-1. A manufactured home elevated on a perimeter foundation wall. Although it appears the openings are too high, the bottoms of the openings are less than 1 foot above the top of the interior slab.

NFIP regulations permit enclosed foundations for manufactured homes in SFHA A zones with a requirement that the foundation walls include flood vents. 44 CFR 60.3(c)(5) requires that:

> "all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other covering or devices provided that they permit the automatic entry and exit of floodwaters."

This elevation technique should not be used in high-velocity or highly erosive flood conditions, and is not permitted in V zones. Additional information on wall vents for floodwater flow is provided in FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).

Perimeter walls of enclosed foundations should include adequate reinforcement to resist unbalanced hydrostatic and/or hydrodynamic loads that may occur in fast rising flood events. Such floods may result in water levels higher on the exterior side of the wall than the inside until flow through the flood vents can equalize them.

8.3 Open Foundations and Breakaway Walls

NFIP regulations require manufactured homes in SFHAs designated V1-30, VE, or V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls (44 CFR 60.3(e)(5)). Elevating a manufactured home on an open foundation involves raising it onto piers, posts, or piles. If the home is located in an area of coastal flooding, an open foundation is the only way to safely elevate the home. If the home is subjected to high-velocity riverine floodwaters, significant water depth, or potential erosions, the home should also be elevated on an open foundation. Open foundations are intrinsically more resistant to moving floodwaters and breaking waves than enclosed foundations since the home has a smaller surface area exposed to flood forces. Selection of the proper open foundation for various flooding and site characteristics is critical to the success of the foundation.

Breakaway walls, including non-structural skirting around a manufactured home, are walls that are not part of the structural support of the home. They are designed and constructed to fail under the loads imposed by floodwaters without jeopardizing the elevated portion of the home or the structural support of the home. Because such enclosures are designed to fail at a lateral load of no greater than 20 pounds per square foot, they will transfer minimal additional loads to the foundation. Insect screening and latticework both allow floodwaters to pass through. Detailed discussions on design and construction for breakaway walls can be found in FEMA Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls* (2008).

8.3.1 Pier Systems

Most manufactured homes are placed on pier foundations. Although there are many variations, pier foundations fall into two general styles. One style contains pier foundations combined with other components (such as anchors and frame straps) for lateral stability; the second style relies on the piers and their footings to resist all imposed loads. The foundation styles that use supplemental lateral-supporting devices often do not require reinforced piers. The determination of the need for and the amount of reinforcing required is part of the design analyses. The final design requirements for pier reinforcing is a function of the combination of flood, wind, and seismic loads acting on the manufactured home, and the resulting pier capacity required to resist flotation, collapse, or lateral movement.

When flood velocities are less than 1 fps, piers can be constructed using unbonded (dry-stacked) concrete blocks or steel piers. When pier foundation systems are used without separate components to resist lateral loads, the piers and footings must be much stronger. They not only have to transfer all imposed loads to the bearing soils, but also must do so in a manner that does not damage the piers and footings or overload the supporting soils.

Piers designed to resist lateral and/or uplift loads without the use of ground anchors or straps typically consist of reinforced brick masonry, reinforced concrete masonry units, or reinforced cast-in-place concrete with steel reinforcing bars for both the piers and the below-grade footings. Because the ground around pier footings in SFHAs can be susceptible to erosion and scour, the footings must be embedded below the anticipated scour depth.

In areas exposed to moving floodwaters, special consideration must also be given to controlling scour around the pier foundation elements. Moving floodwaters can remove soil around and beneath foundations, potentially reducing their load capacity to the point of foundation failure.

Floodwaters with high flow rates and floodwaters that carry a large sediment load create more scour than low velocity or clear water flood flow. Because of this, scour is particularly damaging where floodwaters converge or abruptly change direction. Scour is generally greatest around discrete interior piers and the corners of perimeter wall foundations.

Scour removes soil particles from beside and, in severe cases, from beneath foundations. The loss of soil around and/or beneath a foundation affects its capacity to support the design loads. The loss of vertical foundation capacity can result in large settlements and potential collapse. The loss of lateral capacity not only reduces the capacity of the foundation to resist lateral wind and flood loads, but also can reduce the vertical capacity. The loss of lateral support for long thin vertical elements (e.g., single block masonry stack piers) can result in buckling under the design vertical loads.

Piers designed to resist lateral and/or uplift loads must be constructed using mortared horizontal joints between courses and reinforced grout used to fill the vertical cell. The piers must be firmly attached to the supporting footings.

8.3.1.1 Reinforced Pier Systems

Reinforced piers typically have steel reinforcements placed inside of the piers. Reinforced pier systems are commonly constructed of concrete masonry units (CMUs) or cast-in-place concrete (Figure 8-2).

In high-wind areas and in areas exposed to seismic or hydrodynamic loads, piers may require much larger footings to ensure applied loads do not exceed the soil's bearing capacity or allow tensile forces to develop in foundation elements in the upstream and windward side of the home. Laterally bracing the piers can allow the structure to distribute imposed loads to the entire foundation system. Lateral bracing also provides protection against buckling failure of vertical elements due to loss of confining soil from erosion or scour.

Concrete Masonry Unit (CMU) Reinforced Piers

The *International Residential Code* limits the height of solid masonry piers, including hollow concrete masonry units filled solidly with concrete or Type M or S mortar to ten times their least dimension. The height limitation for unfilled hollow concrete masonry unit piers is four times their least dimension (IRC§606.6).

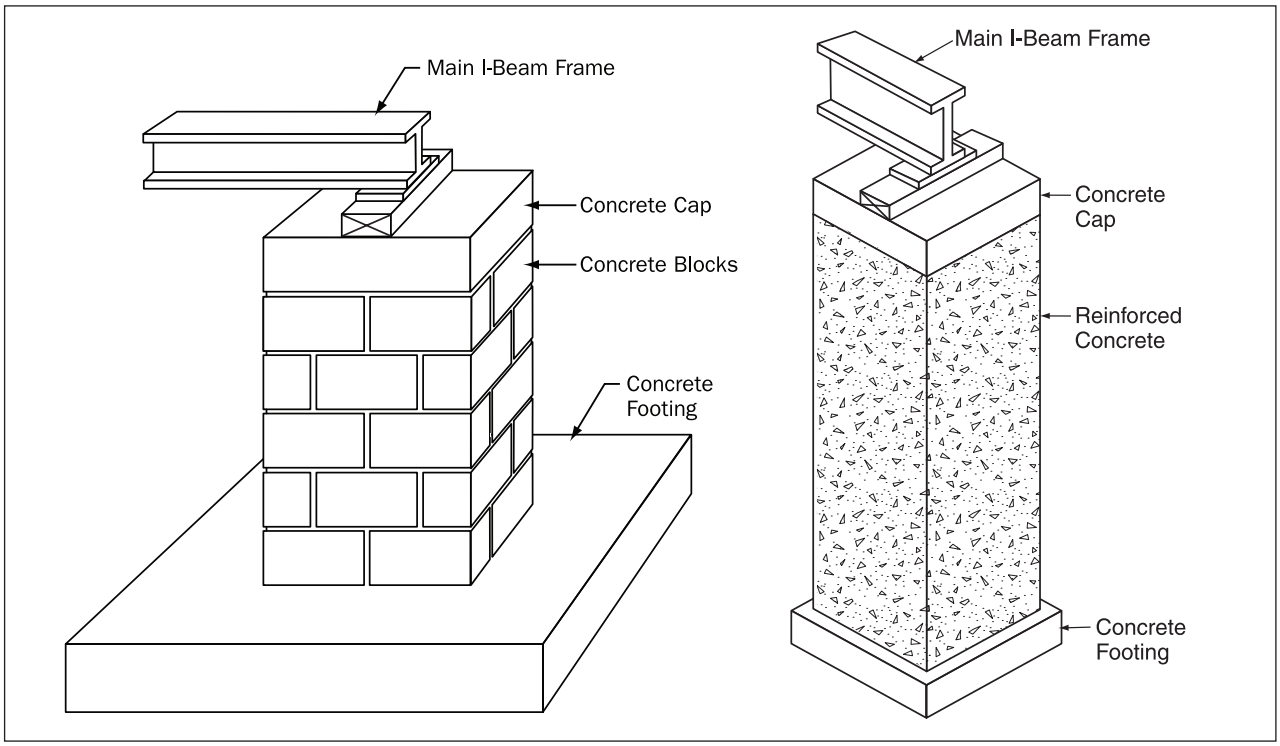


Figure 8-2. Reinforced masonry and concrete piers.

Adequate connections between the piers and the manufactured home are necessary for the manufactured home and its foundation to resist lateral and uplift loads from floods, winds, and earthquakes. Generally, multiple fastener bolted connections are needed to connect the top of the piers to the manufactured home frames when the piers must transfer moments. If the piers must resist only uplift loads, fastening requirements may be simplified. Regardless of the complexity of the connection, consult the manufactured home manufacturer to ensure the factory built components are not overloaded. Figure 8-3 shows a method used to fasten a home's steel frames to reinforced masonry piers using nuts, steel plates, and bolts grouted into the piers.

8.3.1.2 Unreinforced Pier Systems

Unreinforced brick or CMU pier systems have no reinforcing steel and, therefore, have very little resistance to overturning, sliding, and uplift. Because of this, unreinforced piers should always be provided with other stabilizing devices like ground anchors.

When used with stabilizing devices, many styles of unreinforced piers are available to support manufactured homes; the styles provide varying degrees of strength to resist loads on the home. These systems can be constructed without mortar (called dry-stacked masonry); with dry-stacked block lightly secured with a surface bonding material; with mortared block; or with fully mortared, grouted block.

Dry-Stacked Piers

Dry-stacked block piers can fail when a home is exposed to combined wind and ooding (ASCE 7, Load Combination #6). Failure results when wind forces lift the manufactured home's frame off its windward piers. Without the weight of the home to stabilize the piers, the piers can easily fail by sliding or overturning.

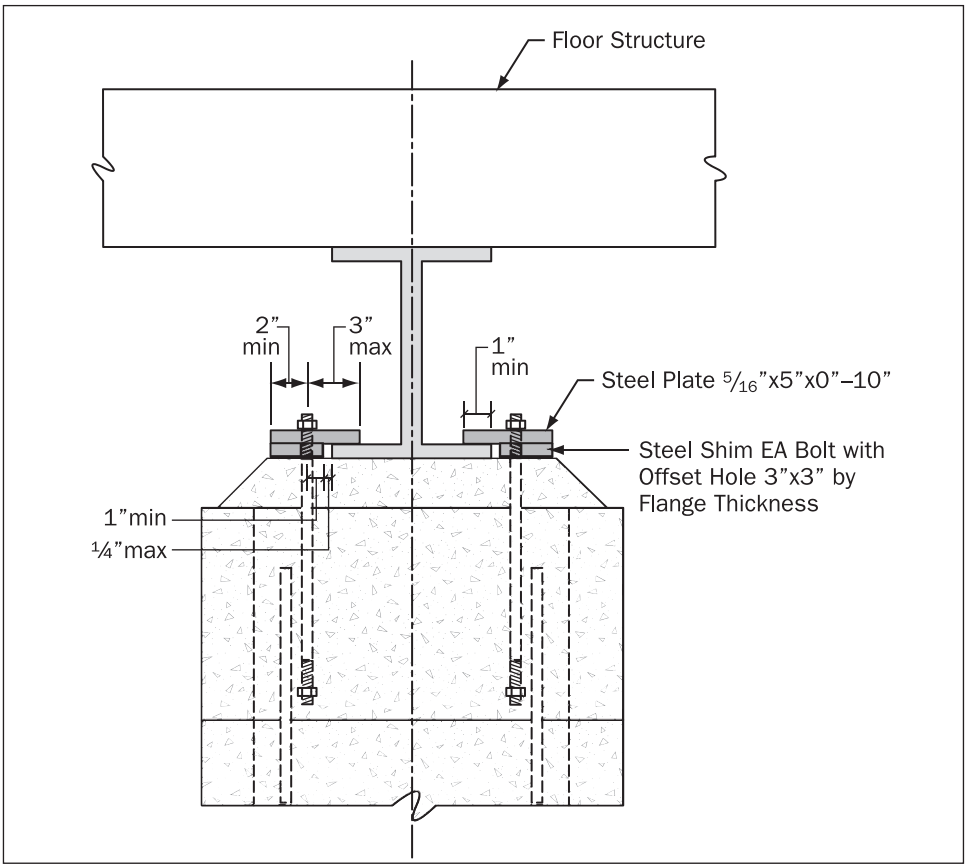


Figure 8-3. Bolted connection between frame and reinforced pier.

When placed directly on concrete footings or pads, 3-foot tall piers constructed with single, dry-stacked blocks to create an 8-inch by 16-inch pier can only resist flood velocities of approximately 1.0 fps. Three-foot tall (16-inch by 16-inch) double-stacked piers can resist flood velocities of approximately 1.75 fps. Dry-stacked piers or posts supported on ABS pads fail at lower velocities than piers supported on concrete. The failure at lower velocities is due to a reduced frictional resistance between the pier blocks or posts and the ABS pad. The design flood velocity for double-stacked piers on ABS pads is 1.25 fps.

If dry-stacked piers are not fully submerged, they can resist higher flood velocities. This is because the portion of the pier above the water line adds to the pier's stability but does not add to the flood load that the pier must resist. Engineers can calculate the ability of partially submerged piers to resist moving floodwaters or their resistance can be determined by testing.

Applying surface-bonding materials strengthens the piers by increasing their shear resistance. However, surface bonding has limited impact on their resistance to bending moments from lateral loads; therefore, surface bonded piers still need to be used with other foundation components. The increased shear resistance allows 3-foot tall (16-inch by 16-inch) piers to resist hydrodynamic loads from floodwaters moving at approximately 2.0 fps for single-stacked piers and 3.0 fps for double-stacked piers. This resistance to moving floodwaters can only be achieved when the surface bonding materials not only bond the individual pier blocks to each other, but also the pier to the concrete footing below. A FEMA sponsored testing program conducted at the Haynes Coastal Engineering Laboratory, Texas A&M University verified the design values.

The Texas A&M testing program included piers constructed using a polyurethane based masonry adhesive as joint bonding material. The Illinois Tool Works (ITW) TACC Division's Mason Bond was certified by ICC Evaluation Service as meeting the IBC and IRC for Types M, N, O, and S Portland cement/lime mortar. Test results showed the single stack adhesive bonded piers to be the strongest configuration tested.

Mortared block and fully grouted mortared block are much stronger than dry-stacked and surface-bonded piers, but their strengths do not match piers with #3 reinforcing steel bars grouted into the vertical cells. Mortared and fully grouted piers usually require other foundation components (like shear walls) to resist lateral loads.

Reinforced piers (constructed by introducing reinforcing steel to fully grouted piers) can be made to resist lateral and vertical loads when used with other foundation components like large concrete footings.

Unreinforced piers cannot be used in V zones. In Coastal A zones, fully grouted piers may be adequate for low flood velocities, but reinforcing with steel is recommended.

8.3.2 Pile Foundations

Pile foundations provide protection for the broadest range of flooding conditions. This foundation system consists of the pile supports, horizontal beams, longitudinal support under the manufactured home, and foundation bracing for additional resistance to lateral wind, floodwaters, and seismic events. A properly designed pile foundation can withstand high-wind and water velocities, and can resist erosion and scour around its base if embedded to an adequate depth (Figure 8-4). Because of this, pile foundations meet the NFIP requirements for installation in V zones. Pile foundations are also appropriate for Coastal A zones and for areas exposed to high-velocity riverine flooding.

Figure 8-4. Manufactured home on a pile foundation.

Saturated soils with low bearing capacities are less of a stability problem for a pile foundation than for a pier foundation; thus, pile foundations are preferable in coastal areas. The design of pile foundations requires determining the number, size, length, and location of piles appropriate to the particular manufactured home, soil conditions, and flooding situation at the site. A pile design methodology is provided in the *Coastal Construction Manual* (FEMA 55) that requires input parameters, including soil property and loading information.

Piles are vertical supports similar to posts, but differ in the method and depth of placement. Piles are embedded much deeper than posts and do not rest on footings for resistance. Instead, the piles are driven until they rest on a solid support layer, such as bedrock, or until they are embedded deep enough that the friction between the ground and the piles will enable them to resist the gravity, lateral, and uplift loads expected to act on them.

The most commonly used piles in residential construction are wood. Steel and precast concrete piles are also used. Pile foundations are primarily used in areas where other elevation methods are not feasible, such as V zones.

A major consideration in the effectiveness of pile foundations is the method of installation. Piles are placed into the ground by impact driving, water jetting, augering, or some combination of these methods (Figure 8-5). Piles are often driven by a single- or double-acting diesel hammer or an air/steam hammer. Pile driving is an excellent method due to the strength of the pile and the ability of the pile and its soil interface to resist vertical and horizontal loads.

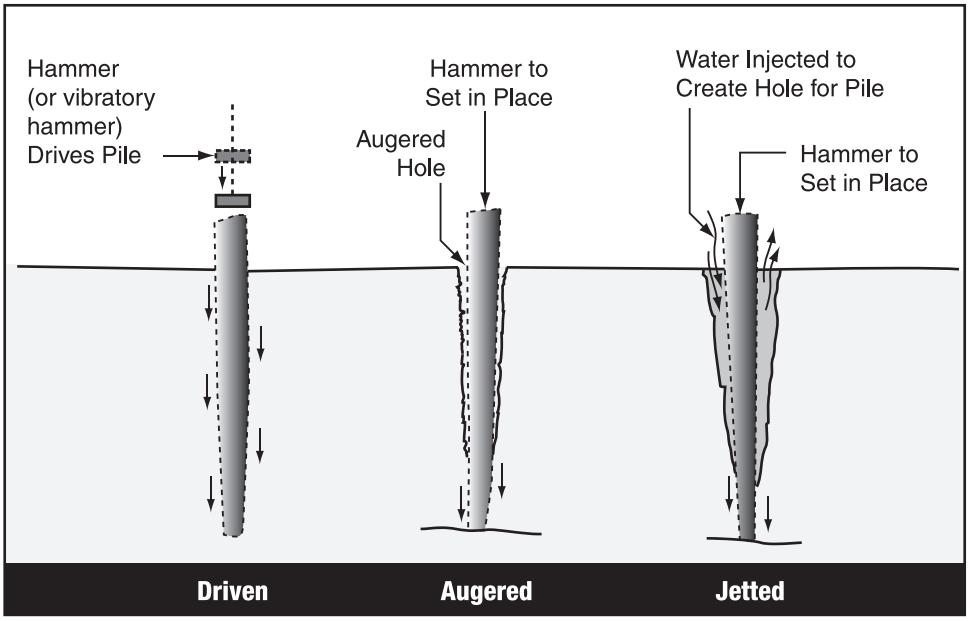


Figure 8-5. Pile driving methods.

A less desirable, but frequently used method is jetting. Jetting inserts piles into sandy soil by forcing a high-pressure stream of water through a pipe along the side of the pile. The stream of water creates a hole in the sand while the pile is continuously pushed or dropped to the desired depth. Jetting results in a lower load capacity due to loose soils that create decreased friction between the piles and the surrounding soil. Jetted piles must be inserted deeper into the ground than driven piles in order to achieve the same load capacity.

Another method is the use of an auger to pre-drill holes for piles. If the soil is composed of adequate clay or silt, using an auger to create holes for piles is sufficient. Additionally, some sands may contain enough clay or silt to permit the use of an auger. This method can be used by itself or in conjunction with pile driving.

Pile installation methods, including driving, jetting, and, to a lesser extent, augering can make precise location control difficult. Also, irregularities in the piles and soil will often prevent the piles from being driven perfectly vertical. When using piles to support manufactured housing, wood beams are typically secured to the piles and the home is secured to the beams.

When soils near the top of a pile are lost due to scour, the pile loses some of its ability to resist vertical and lateral loads. Erosion and scour must be taken into account when determining pile embedment depth and lateral bracing requirements. Due to the variability associated with differing installation methods and erosion/scour potential, a geotechnical engineer should be involved in the design process to verify that intended pile capacities are achieved.

8.4 Bracing

Bracing is often used to lower the point of application of lateral loads to reduce moments applied to the foundation system (cross bracing) or to provide lateral support to resist buckling (knee bracing). Diagonal bracing runs diagonally from one vertical supporting member to another, stiffening the vertical supporting members and increasing their strength and lateral stability (Figure 8-6). Unfortunately, with greater strength comes a larger exposure to wave and debris impact. Diagonal bracing is too slender to resist compressive forces and is typically only designed to carry tension forces. This technique of bracing is especially beneficial in higher elevated homes.

Steel rods are often used to diagonally brace wood posts or piles. The rods are fitted through drilled holes filled with wood preservative and fastened with nuts and cast beveled washers. Rod bracing offers two important benefits. One, rod bracing can easily be fitted with turnbuckles that allow bracing to be tightened after an event that creates loads in the bracing; two, rod bracing has smaller cross-sections than bracing created with dimensional lumber and thus is exposed to lower flood forces.

Knee bracings are short diagonal braces that run from a vertical support member to a horizontal support member (Figure 8-7). Knee braces can be effective in supporting the pile against the lateral forces of wind and water, Knee bracing increases the strength and stiffness of the extended pile foundation by retraining rotation near the top of the pile and reducing the pile bending length. Knee bracing is not as stiff as diagonal bracing. Knee braces have an advantage over diagonal braces in that they present less obstruction to waves and debris. Knee braces are shorter than diagonal braces and are usually designed for both tension and compression forces. Engineers should be consulted to determine bracing designs, particularly for knee bracing.

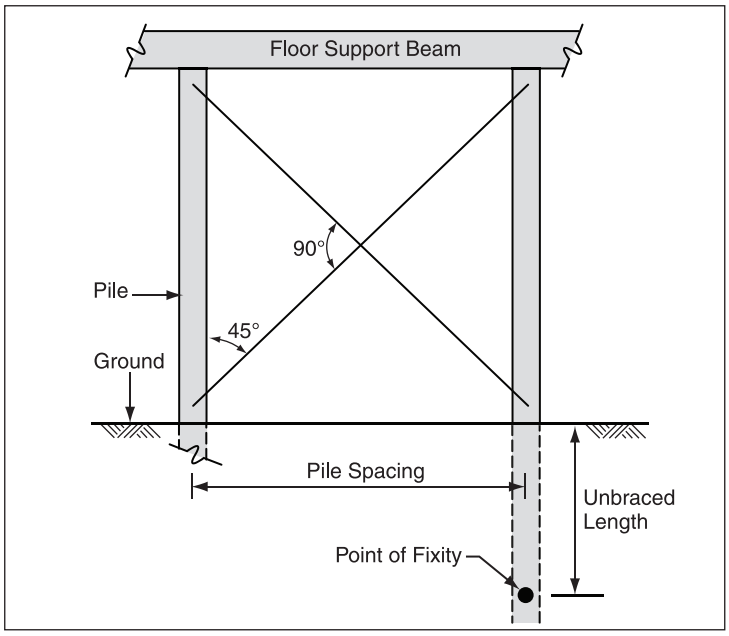
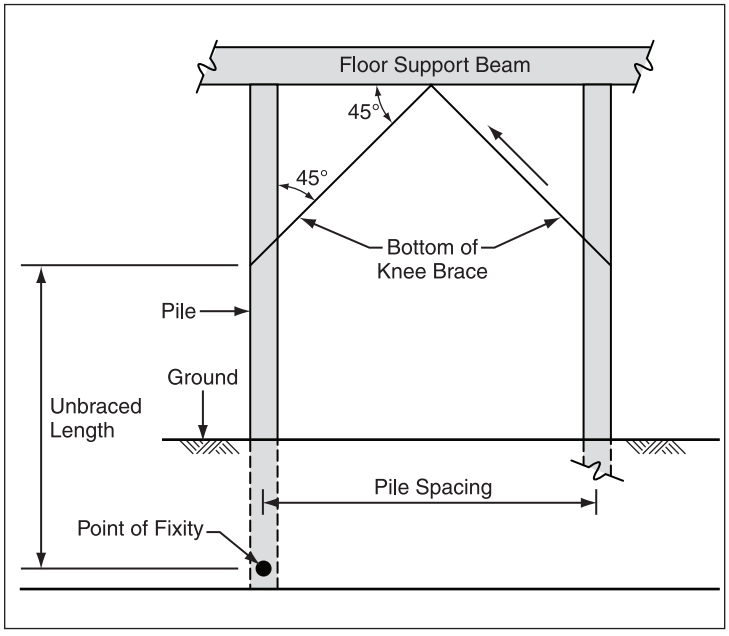


Figure 8-6. Diagonal bracing.



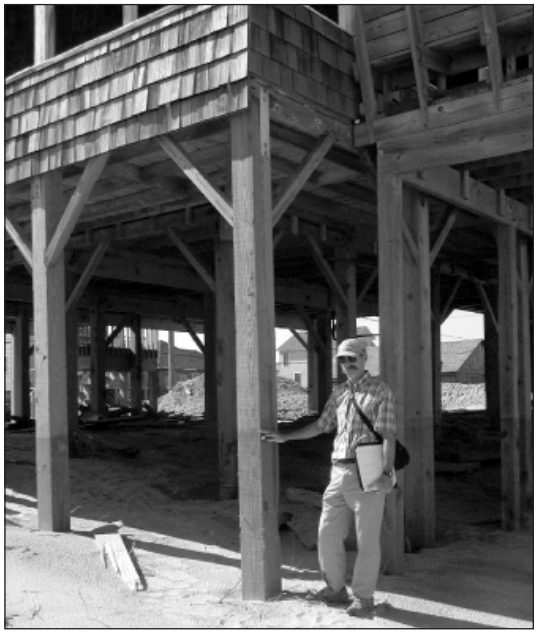


Figure 8-7. Knee bracing.

8.5 Footings

Footings are the components of a foundation system that transfer loads applied to a home to the earth below it. Footings continuously support gravity loads (and are generally well designed for this purpose), but they also must transfer lateral and uplift loads produced by wind events, seismic events, snow accumulation, and moving floodwaters.

The soils below the footings must support the home and resist all the loads applied to the home. When soils are strong, footings can be relatively small and foundation systems relatively compact. When soils are weak, however, the footings become large, complicated, difficult to construct, and quite expensive. Even when placed on firm soils, footings often need to be oversized to provide sufficient weight to resist uplift forces and overturning moments.

The design size of a pier footing is a direct function of soil bearing capacity. Soil bearing capacity can be directly determined by soils tests. In some jurisdictions, approximate bearing capacity can be assessed by soil classification. Model building codes (such as the IBC and NFPA 5000) have presumptive soil bearing capacity values that can be used in the absence of soils test data.

The depth of the footings depends on local frost levels and expected scour depths (whichever is greater). Local codes may provide specific requirements for the depth of footings based on local soil conditions.

8.6 Foundation Materials Selection

As stated in 44 CFR 60.3(a)(3), all structural and non-structural materials at or below the BFE must be flood damage-resistant. A flood damage-resistant material is defined as any building material capable of withstanding direct contact with floodwaters for 72 hours without sustaining significant damage (i.e., damage requiring more than low-cost cosmetic repair, such as painting). In addition, materials should be durable and resistant to decay and corrosion.

Some flood damage-resistant foundation material choices include the following:

- Pressure-treated lumber
- Naturally decay-resistant lumber (only for applications above grade)
- Concrete: a minimum 28-day compressive strength of 5,000 lb/in^2 is recommended in coastal environments
- Masonry: reinforced and fully grouted in coastal environments
- Steel: corrosion-resistant
- Closed-cell foam insulation
- Other flood damage-resistant materials approved by local building officials

The most commonly used foundation materials are wood, concrete, steel, and masonry. Their properties, advantages, and special considerations are discussed in Sections 8.6.1 through 8.6.4. Additional information on materials' durability can be found in FEMA 55 and trade organization publications. FEMA's Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008) also contains information on appropriate materials used in SFHAs.

8.6.1 Wood Foundations

Wood is a very workable material and one of the most cost-effective; however, it is susceptible to decay, insect infestation, marine borers, and weathering. Wood must be adequately maintained to ensure the foundation's integrity. All wood used in foundation piles, girders, beams, braces, and walls must be pressure-preservative treated or, when not in direct contact with the ground, naturally decay-resistant. No wood with natural resistance to decay is considered to have sufficient decay resistance for ground contact or partial water immersion. Wood exposed to the ground and exterior elements should be pressure-preservative treated to increase its resistance to infestation and decay. The degree of resistance depends on the treatment chemical and the amount of retention in lb/ft^3 of wood.

The preservatives used in pressure treating wood for foundation applications; e.g. piles, piers, and posts, include:

- chromated copper arsenate (CCA)
- pentachlorophenol
- creosote
- copper azole

ACQ- or ACZA-Treated Wood

Designers and builders considering the use of ACQ- or ACZA-treated wood should consider using stainless steel hardware and fasteners or obtain the latest information on the chemicals' interaction with hardware due to reports of alleged problems with corrosion of galvanized framing hardware and nails in contact with wood treated with these chemicals.

8.6.2 Concrete Foundations

Concrete is an economical and workable foundation material that is extremely good at resisting compressive loads. Concrete can be reinforced to increase its ability to withstand tensile loads that often result from flood, wind, and seismic activity. Corrosion of the reinforcement and the cracking of the concrete weaken the concrete structural element, reducing its ability to resist loads. Providing adequate concrete cover to reinforcement is the best defense against corrosion. Consult the latest version of American Concrete Institute (ACI) publication 318, *Building Code Requirements for Structural Concrete*, for minimum concrete cover requirements. Additional protection from corrosion can be achieved by using epoxy-coated reinforcement.

Proper mixing, placement, and curing are essential for durable concrete. During placement, concrete will normally require vibration to eliminate air pockets and voids in the finished surface. The vibration must be sufficient to eliminate the air, but not to separate the concrete or water from the mix. Appropriate freeze protection may be needed if pouring is done in cold temperatures. Concrete placed in cold weather takes longer to cure, and the uncured concrete may freeze, which will adversely affect its final strength. Methods of preventing concrete from freezing during curing include the following:

- Heating adjacent soil before pouring
- Warming the mix ingredients before batching
- Placing insulating blankets over and around the forms after pouring
- Selecting a cement mix that will shorten curing time

Because the environmental impact of salt-laden air and moisture make the damage potential significant for concrete, this guide recommends that all concrete construction in and near coastal flood hazard areas (both V and A zones) be built with the more durable 5,000-pounds per square inch (psi) minimum compressive strength concrete regardless of the purpose of the construction and the design loads.

8.6.3 Steel Foundations

Prefabricated steel stands are available for supporting manufactured housing. Like unreinforced masonry piers, steel stands have little resistance to overturning and should only be used in conjunction with other foundation components like ground anchors or perimeter shear walls. Metal stands should also be firmly secured to the homes' frames.

8.6.4 Masonry Foundations

Reinforced masonry has much more strength and ductility than unreinforced masonry for resisting large flood, wind, and earthquake forces. It is recommended that permanent masonry construction in and near coastal flood hazard areas be reinforced and fully grouted regardless of the purpose of the construction and the design loads. Moisture can have a damaging effect on masonry construction. Moisture-borne salts in coastal environments entering the piers through cracks or openings in the masonry joints can cause cracking and spalling of the masonry. Moisture entering piers in cold weather environments can expand upon freezing, causing small cracks to become large cracks. The entry of moisture into reinforced masonry construction can lead to corrosion of the reinforcement and additional cracking and spalling of the masonry. Moisture resistance is highly influenced by the quality of the materials and the quality of the masonry construction at the site. For CMUs, choosing Type I "moisture controlled" units and keeping them dry in transit and on the job will minimize shrinkage and cracking. For optimum crack prevention, Type S mortar should be used for below-grade applications and Type M mortar may be used for above-grade applications.

Open Masonry Foundations

Open masonry foundations in earthquake hazard areas require special reinforcement detailing and pier proportions to meet the requirements for increased ductility.

In addition to Portland cement/lime based mortar, polyurethane based masonry adhesives are now available. Care must be taken in the selection and application of masonry adhesives. As a minimum, the selected adhesive must be certified by a nationally recognized organization as meeting or exceeding the requirements for Types M, O, and S cement/lime based mortar and approved for use in masonry construction designed in accordance with applicable provisions of the IRC and IBC.

8.7 Foundation Selection and Flood Resistance

Flooding can have a dramatic effect on the suitability and stability of a manufactured home foundation. But not all floods are the same, and the type of flooding, along with its

char-acteristics and severity at a site, will eliminate many foundation types. Sections 8.7.1 through 8.7.5 provide guidance (for installers, owners, community officials, and designers) on selecting foundations suitable to different flood types and site conditions.

8.7.1 Flooding Types

Flooding can be divided into seven major types: coastal, riverine, flash flood, alluvial fan, mudflow, lake or pond overflow, and poor drainage. Unique hazards are associated with each of these flooding types.

- **Coastal** flooding is usually accompanied by waves, high velocity flow, and erosion. Damages to structures are usually the results of erosion and scour, and direct impact from wave action.
- **Riverine** flooding is associated with dominant hazards, including velocity, depth, and duration. These hazards are determined by several factors, including the slope of the channel and watershed, land uses within the watershed, and the extent, intensity, and duration of precipitation. (Both coastal and riverine flooding can transport damaging debris. Debris impact can weaken a structure and make it more vulnerable to damages from flooding.)
- **Flash floods** are accompanied by rapidly rising water and extreme flood velocities, with high debris carrying potential. Although they are generally of short duration, the forces exerted on structures by the high velocity floodwaters and debris can cause extensive damage in a very short time.
- **Alluvial fan** flooding is distinct in that the region of greatest flood hazard is not well-defined, and floodwaters can follow many different paths across a normally dry area. Alluvial fan floods usually occur in arid areas at the base of steeply sloping terrain, and can have extreme flood velocities and debris loads.
- **Mudflows** are proximately caused by flooding and can be considered a river of liquid and flowing mud on the surfaces of normally dry land areas. Mudslides usually offer little warning and can be very destructive due to their debris load and velocity.
- **Lake or pond overflow** is rarely as hazardous as coastal or riverine flooding, and is usually limited to inundation by slowly moving or standing water.
- **Poor drainage** can lead to backups and generally results in ponding type flooding. Poor drainage is usually caused by a lack of topographic relief to allow for natural drainage from a site, or it might be the result of a specific hindrance such as blockage of a drainage ditch or an undersized culvert. In areas where drainage impediments become severe, they can compound risk and damages from other types of flooding such as riverine or flash floods.

8.7.2 Flood Characteristics

The flood source, its proximity to a site, and the flood hazard zone will provide information about flood characteristics. However, historical flood events at and near the site can also provide important clues about expected flood conditions at the site. All should be considered when home foundations are evaluated.

High velocities, large waves, and large floating debris can cause many home installations to fail, especially those on stacked masonry block, crawlspace, slab, shallow pier, and post foundations. Large flood depths can float or wash homes off their foundations. Long-duration floods can weaken soils, foundations, and anchor systems. Refer to Section 5.2 for more information on flood characteristics.

8.7.3 Flood Hazard Zones

Table 8-1 is provided as general guidance for the selection of foundation systems for manufactured homes located at different flood hazard zones, Different flood hazard zones are represented on FIRMs by different zone designations. Detailed information pertaining to flood hazard zone designations and current NFIP regulations is provided in Chapter 3.

8.7.4 Proximity to Flood Source

Proximity to the flood source will, to a large extent, determine whether a home site is in a more or less hazardous location. As discussed in Chapter 4, sites in a floodway or closest to a river or stream will be subject to the greatest flood depths, highest velocities, and greatest debris potential. Sites outside the floodway and far from a river or stream and closer to the landward limit of the floodplain will be subject to reduced flood hazards (e.g., shallow flood depths, lower velocities, low erosion potential, and only small debris).

Sites in a V or Coastal A zone will be subject to the highest waves, greatest flood velocities and depths, greatest erosion potential, and largest debris. Sites outside the V zone and far from the shoreline will be subject to reduced wave, velocity, depth, erosion, and debris conditions.

Closeness is a relative issue, however. Therefore, it may be useful to look at the location of a home site relative to the flood source or floodplain boundary. Two approaches may be useful, a distance approach and a floodplain width approach.

1. The **distance approach** relies on a distance measurement between the home site and the stream or river bank or floodway (in the case of a riverine flood source), or between the home site and the V zone boundary or shoreline (in the case of an A zone in a coastal area).
2. The **floodplain width approach** considers the relative position of the home site within the floodplain. (See Figure 4-2, which is a schematic of a floodplain/floodway.)

For riverine areas outside the floodway:

1. **Distance approach**: If a home site lies within a few hundred feet of a river or stream or floodway, it should be considered “close,” and foundations should be appropriate to sites with greater flood hazards.
2. **Floodplain width approach**: If a home site lies within the third of the floodplain closest to the river or stream or floodway, it should be considered “close,” and foundations should be appropriate to sites with greater flood hazards.

For Coastal A zones:

1. **Distance approach**: If a home site lies within a few hundred feet of the V zone boundary (or shoreline, if a V zone has not been mapped), it should be considered "close," and V zone foundations should be used. Beyond that point, A zone foundations may be suitable.
2. **Floodplain width approach**: If a home site lies within the half of the floodplain closest to the V zone boundary (or shoreline, if a V zone has not been mapped), it should be considered "close," and V zone foundations should be used. Beyond that point, A zone foundations may be suitable.

8.7.5 Foundation Selection Guidance

The recommendations contained in Tables 8-1 through 8-3 should be evaluated in light of specific soil, terrain, and base flood conditions at a home site. The pier information contained in the tables is appropriate for piers used in foundation systems that contain other components (like ground anchors) that are properly selected, designed, and installed to resist flood and wind forces on the manufactured home itself. The pier construction styles listed are those required to resist flood forces on the piers themselves.

Areas exposed to flash flooding, alluvial fans, and mudslides pose unique (and often not specifically known) hazards. Foundations for homes in those areas should be developed by licensed engineers working closely with local floodplain managers.

Table 8-1. Recommended Manufactured Home Foundation Selection for Lake/Pond Flooding (for very low velocity less than 1 fps)

Lake/Pond Flooding (standing water; maximum flood flow velocity 1.00 fps)		
Flood Zone/Foundation Type		**A, AE, A 1-30, AO/AH**
Steel pier		✓
Dry-stacked masonry block	Single block stack	✓
	Double block stack	✓
Dry-stacked masonry block with surface-bonded mortar	Single block stack	✓
	Double block stack	✓
Mortar or adhesive-bonded masonry block	Single block stack	✓
	Double block stack	✓
Reinforced and grouted masonry block	Single block stack	✓
	Double block stack	✓
Fill/slab		✓
Posts		✓
Perimeter foundation walls		✓
Piles		✓

✓ = OK

fps = feet per second

Single block stack (8 inch by 16 inch) on concrete footing or ABS pad

Double block stack (16 inch by 16 inch) on concrete footing or ABS pad

Table 8-2. Recommended Manufactured Home Foundation Selection for Riverine Flood Zones (and maximum flood flow velocity)

Riverine Flooding			
Flood Zone/Foundation Type		**Floodway[1]**	**A, AE, AE1-30, AO/AH**
Steel pier			✓ V_{max}=1.00 fps
Dry-stacked masonry block	Single block stack	Do Not Use	✓ V_{max}=1.25 fps[2]
	Double block stack	Do Not Use	✓ V_{max}=1.75 fps[3]
Dry-stacked masonry block with surface-bonded mortar	Single block stack	Do Not Use	✓ V_{max}=2.00 fps
	Double block stack	Do Not Use	✓ V_{max}=3.00 fps
Mortar or adhesive-bonded masonry block	Single block stack	Do Not Use	✓ V_{max}=2.50 fps
	Double block stack	Do Not Use	✓ V_{max}=3.00 fps
Reinforced and grouted masonry block	Single block stack	Do Not Use	✓ V_{max}=5.00 fps
	Double block stack	Do Not Use	✓ V_{max}=5.00 fps
Fill/slab		Do Not Use	✓
Posts		Do Not Use	✓[4]
Perimeter foundation walls		Do Not Use	✓
Piles[5]		✓	✓

[1] >kv `lkpqor`qflk fk qeb llat^v obnrfobp `boqf^`^qflk qe^q qeb `lkpqor`qflk tfii klq `^rpb ^ ofpb fk llaibsbip+

[2] V_{max} shown for single stack block on concrete pad or footing. V_{max} = 1.00 fps for single stack block on ABS pad.

[3] V_{max} shown for double stack block on concrete pad or footing. V_{max} = 1.25 fps for double stack block on ABS pad·

[4] Scour protection is recommended around shallow foundations where velocities exceed 2 fps.

[5] Pile foundations are suggested for all sites exposed to ood velocities greater than 5 fps unless designed by a licensed engineer or architect.

✓ = OK

V_{max} = maximum design ood velocity (ft/sec) for foundation type

Single stack (8 inch by 16 inch)

Double stack (16 inch by 16 inch)

Table 8-3. Recommended Manufactured Home Foundation Selection for Coastal Flood Zones

Coastal Flooding				
Flood Zone/Foundation Type		**V, VE, V1-30**	**A, AE, A1-30, AO/AH** (LiMWA area)[2]	**A, AE, A1-30, AO/AH** (Outside LiMWA area)[2]
Steel pier		Do Not Use	Do Not Use	✓ where V_{max}=1.00 fps
Dry-stacked masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=1.25 fps[3]
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=1.75 fps[4]
Dry-stacked masonry block with surface-bonded mortar	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=2.00 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=3.00 fps
Mortar or adhesive-bonded masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=2.50 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=3.00 fps
Reinforced and grouted masonry block	Single block stack	Do Not Use	Do Not Use	✓ where V_{max}=5.00 fps
	Double block stack	Do Not Use	Do Not Use	✓ where V_{max}=5.00 fps
Fill/slab		Do Not Use	Do Not Use	✓
Posts		Do Not Use	Do Not Use	✓[5]
Perimeter foundation walls		Do Not Use	Do Not Use	✓
Piles[1]		✓	✓	✓

[1] Pile foundations are suggested for all sites exposed to ood velocities greater than 5 fps unless designed by a licensed engineer or architect.

[2] The Limit of Moderate Wave Action (LiMWA) is the inland limit of the area affected by waves greater than 1.5 feet.

[3] V_{max} shown for single stack block on concrete pad or footing. V_{max} = 1.00 fps for single stack block on ABS pad.

[4] V_{max} shown for double stack block on concrete pad or footing. V_{max} = 1.25 fps for double stack block on ABS pad.

[5] Scour protection is recommended around shallow foundations where velocities exceed 2 fps.

✓ = OK

V_{max} = maximum design ood velocity (ft/sec) for foundation type

Single stack (8 inch by 16 inch)

Double stack (16 inch by 16 inch)

9 Recommended Design Process and Criteria for Manufactured Home Foundations in SFHAs

9.1 Performance Criteria

Performance criteria for manufactured home foundation systems are provided in the HUD *Manufactured Home Construction and Safety Standards* (24 CFR 3280) and *Model Manufactured Home Installation Standards* (24 CFR 3285). The HUD regulations require that manufactured homes installed in flood hazard areas use foundations, anchoring, and support systems capable of resisting loads associated with the design flood and wind events. Foundation, anchoring, and support systems must be capable of resisting flotation, collapse, or lateral movement.

The *International Residential Code for One and Two Family Residential Dwellings* also requires that residential structures, including manufactured home foundations, be designed and connected to resist flotation, collapse, or lateral movement due to structural loads and stresses from flooding equal to the design flood event (R324.1.1). *IRC Appendix E: Manufactured Housing Used as Dwellings* requires that foundations be designed and constructed to minimize differential movements (IRC AE502.4).

The NFIP regulations also establish performance requirements for structures, including manufactured homes, installed in flood-prone SFHAs. The NFIP requires homes be:

> "adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy." [44 CFR 60.3(a)(i)]

9.2 Design Criteria

To meet the performance requirements outlined in Section 9.1, design criteria must be established that identify the anticipated design loads the structure is expected to experience. Design loads can be categorized as dead loads, live loads, or environmental loads.

Dead loads depend on the weight of the manufactured home, its foundation, and any accessory supported by the structure such as walls, piping, electrical service panels and conduits, and HVAC equipment.

Live loads depend on the weight of occupants, furnishings, and non-fixed equipment and the function of the building or specific space.

HUD 24 CFR 3280.305(g) requires floors be designed to support a minimum uniform live load of 40 psf.

Environmental loads are loads for given recurrence intervals specified by the engineering community and vary with locality. Wind loads (which are proportional to the square of the design wind speed) can exceed 80 psf near coastal areas, while those inland can be as low as 15 psf. Snow loads are non-existent in much of the southern U.S., but can exceed 50 psf in northern and mountainous regions.

Environmental loads that act on manufactured homes and foundations include the following:

Flood loads depend on flood depth, flood velocity, surrounding debris sources, wave effects, elevation of the building relative to the flood condition, and surrounding topography and exposure. Flood loads include hydrodynamic and hydrostatic (including buoyancy) and floating debris impact loads.

Wind loads depend on the geometry (particularly roof shape and pitch) and building height, exposure, and, of course, on the design wind speed for the site. Coastal areas in the U.S. are generally exposed to greater wind speeds than interior areas, but special wind regions exist in mountainous areas.

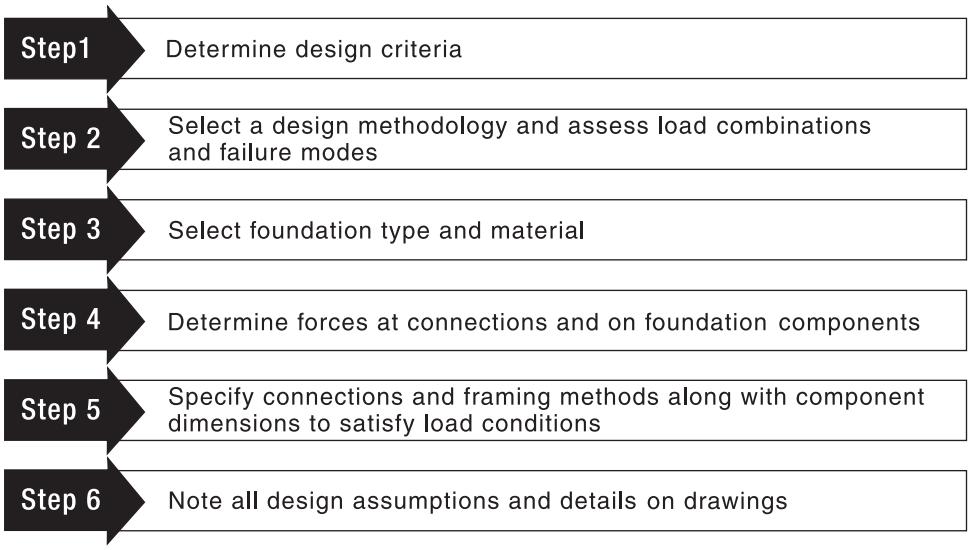
Seismic loads depend on the mass of the building, additional loads that the building may occasionally support (e.g., snow loads), the building geometry and distribution, its lateral force resisting system, and local soil conditions.

Snow loads depend on roof geometry, building orientation, and the geographical location of the site.

Most model building codes contain requirements on estimating the normal and environmental loads on a structure. After the design loads are identified, how these loads interact with the structures can be assessed and the foundation system can be designed.

9.3 Design Process

After the performance criteria are established, the design process can begin. The design process involves the following steps:


Step1
Determine design criteria
Step 2
Select a design methodology and assess load combinations and failure modes
Step 3
Select foundation type and material
Step 4
Determine forces at connections and on foundation components
Step 5
Specify connections and framing methods along with component dimensions to satisfy load conditions
Step 6
Note all design assumptions and details on drawings

Each step of this process is described below. The entire design process is based on the fundamental premise that anticipated normal and environmental loads can and must be transferred through the manufactured home to the foundation in a continuous path to the supporting soils. Any weakness in the continuous path is a potential point of failure of the building, and any failure creates the possibility for large property losses and the loss of life.

This guide does not cover every combination of loads, materials, building shapes and functions, hazard risks, and elevations. Engineering judgment will need to be applied to a range of problems during the design of a manufactured home foundation located in an SFHA. Therefore, the intent of this guide is to provide sufficient background for designers to effectively design manufactured home foundations for forces and issues encountered when sited in an SFHA.

9.3.1 Step 1: Determine Design Criteria

As discussed in Section 10.1, HUD's *Model Manufactured Home Installation Standards* require manufactured home foundations be capable of resisting loads associated with the design flood and wind events. However, the designs do not consider flood or seismic loads (24 CFR 3285.303 footnotes to Tables 1, 2, and 3). The HUD standards do not provide guidance on determining the design criteria for flood and seismic events.

The IRC establishes required minimum design loads for residential structures, including manufactured homes. The IRC requires minimum design wind loads where basic wind speeds exceed 100 miles per hour (mph) in hurricane-prone areas or 110 mph elsewhere shall be in accordance with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. ASCE 7 is a state-of-the-art consensus standard that establishes minimum required design loads to be resisted by structures and their foundations.

9.3.2 Step 2: Select a Design Methodology and Assess Load Combinations and Failure Modes

9.3.2.1 Design Methodology

The two predominant design methods being used in engineering practices today are allowable, or working, stress design (ASD) and strength design. ASD (sometimes referred to as elastic design) is based on the calculated stress in members due to service loads. Strength design (also known as limit state design) is based on ultimate loads (i.e., the load that will cause a member to fail) and the mode associated with the failure. For designing manufactured home installation, either ASD or strength design methodology is acceptable.

9.3.2.2 Load Combinations

After the design criteria are determined, the possibility of more than one hazard occurring at the same time must be considered for all modes of failure as well as the possibility of imposed loads counteracting gravity loads. For example, it is common to expect simultaneous flooding with high winds during hurricane events. In similar situations, uplift forces due to the high winds from hurricanes can counteract gravity loads. Load combinations are used to assess the probability of more than one hazard occurring simultaneously and the probability of imposed loads exceeding gravity loads. Refer to Section 5.5.1 for a discussion of ASCE 7 load combinations.

Load combinations must be resolved directionally so that all loads in a given combination are acting in the same direction, either vertically or horizontally. The Commentary in ASCE 7 states "Wind and earthquake loads need not be assumed to act simultaneously. However, the most unfavorable effect of each should be considered in design, where appropriate. In some instances, forces due to wind might exclude those due to earthquake, while ductility requirements might be determined by earthquake loads."

All design loads create forces in and on the building. All forces acting on the manufactured home must be transferred through the foundation and into the soil that supports the structure. The foundation designer must ensure integrity of this load path. The primary failure modes in load path integrity include uplift failure, overturning, and sliding (or shearing).

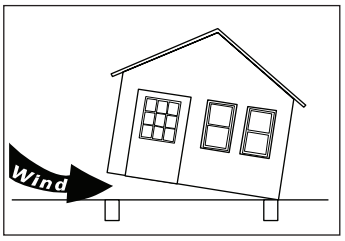
9.3.2.3 Primary Failure Modes

Uplift failure occurs when vertical forces caused by wind or buoyancy exceed the weight of both the structure and the strength of the soil anchorage. The structure fails by being lifted off its foundation or because the foundation pulls out of the soil.

Uplift failure mode is particularly likely when the 3-foot pier rule is used in areas where the BFE is greater than 3 feet above the ground elevation. In that situation, the home will become submerged and exposed to buoyancy forces. For relatively low levels of flooding (9 to 12 inches or less), buoyancy forces can exceed the weight of the home and lift the home off its foundation. To resist buoyancy, foundations must provide sufficient resistance to overcome buoyancy (and

wind) and all connections between the home's foundation must be designed to prevent flotation, collapse, or lateral movement, of the submerged home (Figure 9-1).

Figure 9-1. A home that was partially submerged and displaced from its foundation by hydrostatic forces. Although it appears the openings are too high, the bottoms of the openings are less than 1 foot above the top of the interior slab.



Overturning failure occurs when the combined forces of wind, waves, and buoyancy or earthquake exceed the resisting forces of the building's weight and anchorage. The building fails by rotating off its foundation or rotating out of the soil (see Figure 7-8).

Sliding or shearing failure occurs when horizontal forces exceed the friction force or strength of the foundation. The building fails by sliding off its foundation, shear failure of components transferring loads to its foundation, or the foundation sliding.

All three of these failure modes can result in a wide range of damage, from minor, such as loosening of the anchor straps, to catastrophic, such as structural collapse. It is important to emphasize that other load combinations and failure modes may exist, and professional judgment should be exercised in any situations not covered by this guide.

9.3.3 Step 3: Select Foundation Type and Material

After loads are determined and failure modes are assessed, the foundation type and materials must be selected. Both are described in Chapter 8 as well as advantages and special considerations for the selection process.

9.3.4 Step 4: Determine Forces at Connections and on Foundation Components

The loads on components and at connections through the load path must be determined to design an adequate foundation. Some examples of critical points of the load path include the following:

- Connections between the site-built foundation and the home's steel frames (and the home's wall ties if in higher wind zones)
- Load path connections through the site-built foundation
- Load path connections from the foundation to footings
- Adequacy of the footing and surrounding soil

9.3.5 Step 5: Specify Connections and Framing Methods Along with Component Dimensions to Satisfy Load Conditions

The loads determined in Step 4 are used in the design and detailing of connections, foundation components, and anchoring. The loads at connections will be used to design the connections (i.e., number of bolts or nails, size of clip angles). The reactions at the support points will be used to design the foundations (i.e., size of piers and footings, amount of reinforcement, and spacing between piers and ground anchors).

Components and connections design should meet the requirements of an appropriate material standard, some of which are listed in Table 9-1.

Table 9-1. Design Standards and Publishers for Building Materials

Building Material	Standard and Publisher
Wood	*K^qfIk^i Abpfdk Pmb`fa` ^qfIk* (NDS) *for Wood Construction* and *Commentary* published by American Forest and Paper Association (AF&PA)/American Wood Council (AWC)
Steel	*Manual of Steel Construction* (AISC 325-05) published by American Institute of Steel Construction (AISC)
Concrete	*Building Code Requirements for Structural Concrete* (ACI 318) published by American Concrete Institute (ACI)
Masonry	*Building Code Requirements for Masonry Structures* (ACI 530) published by ACI

9.3.6 Step 6: Note All Design Assumptions and Details on Drawings

To ensure a quality design and installation, all assumptions, calculations, and details should be clearly documented or noted on the construction documents so that installers and floodplain managers clearly understand the design and design assumptions.

Appendix F provides a detailed example of vertical and lateral load, overturning moment, and, foundation and ground anchor calculations.

10 Recommended Foundations

Manufactured home foundations must be designed and constructed to resist gravity, lateral, and uplift loads. Foundation systems provide load resistance by transferring the loads to soils at the site. Load transfer can be accomplished using a single element or a combination of elements. For example, driven piles are an effective foundation element for transferring gravity, lateral, and uplift loads to the soil. Unreinforced masonry piers can be effective at transferring gravity loads, but are not effective in transferring lateral and uplift loads.

This chapter provides descriptions and design recommendations for six foundation systems suitable for use in many SFHAs in the U.S. The six foundation systems presented are: reinforced masonry, wood framed, braced masonry pier, wood H-frame, ground anchors with stabilizer plate, and ground anchor (in-line). These foundations can be used for sites in A zones with low to moderate floodwater velocities and depths. They are not suitable for V zones, Coastal A zones, and home sites in floodways or other high velocity areas.

Also included in this chapter are three foundation designs suitable for all seismic regions in the U.S. The seismic designs can only be used for sites with maximum 90-mph design wind speeds.

Although the foundation designs can be used in many flood areas, they are not "all inclusive" and do not provide a "one-size-fits-all" design. Because natural loads vary greatly from site to site, any single design may be overly conservative in some areas, but would provide inadequate protection in other areas.

10.1 Design Criteria for Recommended Foundations

Criteria used in the design of the recommended foundations were selected to provide a balance between cost and applicability. Homes placed in areas where anticipated events exceed the design criteria used will require custom designed foundations. Foundation designs provided in this guide are not appropriate for manufactured homes within V zones, Coastal A zones, floodways, and all sites where design event flood velocities exceed 5 fps. The recommended foundations were designed to the following criteria:

- Maximum flood depth of 36 inches above finished grade.
- BFE no higher than the bottom flanges of the home's I-beams.
- Maximum flood velocities of 5 fps.
- No breaking wave forces.

- 3-second gust wind speeds of 90 mph, 110 mph, 130 mph, and 150 mph. The seismic foundations (drawings SP, SM, and SWF in Appendix H) may be used in areas with design 3-second gust wind speeds of 90 mph or less.
- Manufactured home with width of at least 14 feet wide for single units and 28 feet wide for double units. Minimum home length of 48 feet for both single and double units.
- Manufactured home eave heights of 8 feet 2 inches or less.
- Chassis main beam spacing of 82 to 96 inches (for ground anchor foundations).
- Maximum snow loads of 40 psf.
- Manufactured home weight of at least 25 psf and not greater than 40 psf.

Foundations have been designed to resist loads and load combinations calculated using ASCE 7. Where additional design guidance was needed, other documents have been used, including the *Coastal Construction Manual* (FEMA 55). A brief description of each design follows in Sections 10.1.1 through 10.1.5. The drawings are presented in Appendix H.

10.1.1 Reinforced Masonry Perimeter Foundation Walls

(Drawing Numbers: M-1 to M-4)

The reinforced masonry (RM) foundation consists of reinforced masonry walls supported on cast-in-place concrete strip footings.

Reinforced masonry perimeter walls transfer gravity loads to the soil through the bearing pressure imposed on the strip footing. Lateral loads are resisted by a combination of frictional resistance between the strip footing and the soil, and lateral resistance of the soil against the below grade portion of the wall footing. Uplift loads are resisted by a combination of the weight of the footing, soil resistance to vertical failure, and increased bearing pressures in the leeward footing.

RM foundations are likely the most expensive of the recommended foundations that have been developed. For example, properly grouting the masonry wall cores will likely require the home to be crane set on the RM foundation.

Openings or vents, required by the NFIP, are spaced throughout the foundation walls. The openings are designed to automatically allow floodwater to enter the crawlspace and equalize hydrostatic pressures on the foundation walls. Flood openings must automatically open to allow floodwaters to flow and must be installed within 1 foot of grade. Detailed guidance for flood openings is provided in FEMA Technical Bulletin 1: *Openings in Foundation Walls and Walls of Enclosures*, August 2008. A minimum of two flood vents with a total net area of 1 square inch per square foot of enclosed space must be provided (44 CFR 60.3(c)(5)). Vents for moisture control are typically installed at the top of the foundation wall. In areas where high crawlspace moisture levels predominate, additional vents may need to be installed in the upper portions of the foundation walls for adequate ventilation.

Final connections between the factory-built home and the site-built foundation are made by bolting the home to the foundation wall anchor bolts (if an adequately attached pressure-treated sill plate is provided with the home) or by anchoring a pressure-treated sill to the foundation wall and installing framing clips between the site-installed sill plate and the home's band joist (if a pressure-treated sill is not provided with the home).

10.1.2 Wood Framed Perimeter Foundation Walls

(Drawing Numbers: WF-1 to WF-4)

The wood framed (WF) foundation consists of 2-inch by 6-inch (nominal) treated framing sheathed with plywood that is treated to resist rot and wood destroying insect damage. The WF foundation walls are constructed over continuous poured concrete strip footings. Like the RM foundation, the WF foundation encloses the underside of the home to create a crawlspace, and flood vents are required to equalize hydrostatic loads and provide crawlspace moisture control. Because wood framed walls resist less shear per unit length than masonry, the WF foundation design requires interior shear walls to adequately resist lateral (wind, flood, and seismic) loads. In higher wind zones, plywood sheathing is needed on both sides of the shear walls.

Unlike the RM foundation wall design, the WF foundation was designed to enable "building to the box." Footings can be poured prior to placing the home (for installation tolerance, they can be constructed slightly wider), the home can be rolled onto the sites, and the walls can be constructed between the factory-built home and the site-built foundation.

A home destined to be placed on a WF perimeter foundation will require some fabrication modifications. Most notable is the need to shorten outriggers to avoid interferences with the foundation wall. Shear reinforcement may be necessary to adequately transfer lateral and vertical loads from the home to the foundation. Manufacturers should provide connection details specific to their homes.

10.1.3 Braced Masonry Pier Designs

(Drawing Numbers: BM-1.1 to BM-2.2)

The braced masonry pier (BMP) designs utilize materials developed for more typical foundations. The BMP designs use metal straps and masonry piers found in ground anchor foundations. But instead of using ground anchors to resist vertical and lateral loads, the weight of continuous concrete footings are used to resist uplift and soil pressure while friction forces resist lateral loads.

Pier construction varies with flood velocity. With low flood velocities, piers can be dry stacked and adhered with surface bonding mortar. For increased flood velocities, piers with greater lateral strength are needed to ensure that they do not become dislodged under the combined effects of wind (or seismic) loads and flood loads. Increasing design flood flow velocities require that the masonry piers be strengthened to resist higher loads. Section 10.3 outlines flood flow velocity design considerations for several masonry pier configurations.

The metal straps are an integral component in the braced masonry foundation. Failure of any strap will redistribute loads to adjacent portions of the foundation. If straps are loaded to their maximum working load, redistributing the load can lead to progressive strap failure and home collapse. To reduce potential for progressive failure, redundant straps have been included in the designs.

10.1.4 Wood H-Frame Designs

(Drawing Numbers: HF-1.1 to HF-2.2)

The wood H-frame designs are similar to pile foundations used to elevate structures in coastal areas. The greatest difference between the two designs is the use of the weight of concrete footings to resist uplift and lateral forces instead of the friction between earth soils and piles.

The designs allow setting the manufactured home on the site and constructing the H-frames from below. This "building to the box" provides flexibility in site construction, but some installers have expressed concerns regarding the amount of work required under the home. Temporary piers or metal jack stands can support the home during construction, or all H-frames can be built and the home can be set with a crane.

A critical component to the H-frame designs is the post bases that connect the vertical posts to the concrete footing. The design specifies cast-in-place bases be accurately positioned during the concrete pour. The fasteners used to construct the frames are sized to resist uplift and lateral forces only. They are not sized to support all gravity loads. Because of this, the posts must be constructed tight to the bottoms of the I-beam frames or provided with shim pairs to transfer gravity loads.

10.1.5 Ground Anchor Designs

(Drawing Numbers: GASP-90-1.1 to GASP-110/130/150-2.2 and GA-90-1.1 to GA-110/130/150-2.2)

In many areas of the U.S., ground anchors are used as part of the support and anchorage systems for manufactured homes. Anchors are inexpensive, easily installed in many types of soils, and readily available in many portions of the U.S. Despite these advantages, support and anchorage systems using ground anchors do not perform as well as typical foundations. Most of the shortcomings result from the fact that shallow earth anchors are relatively weak and their performance is highly variable, and foundations using ground anchors lack the structural stiffness that typical foundation materials provide.

Ground anchors can be effective in resisting uplift and lateral loads. Loads are resisted by mobilizing the soil shear strength along the potential failure surface. The surface area of the potential failure plane is a function of helix area and embedment depth. Mobilization of soil shear strength requires movement along the failure plane. Shallow anchors typically used for manufactured home installations require mobilization of a significant portion of the ultimate soil shear strength, which results in relatively large movements.

Ground anchors used in manufactured home installations frequently use stabilizer plates to enhance lateral load resistance capacity. The stabilizer plates resist lateral loads by mobilizing passive resistance of the soil. Development of soil passive resistance requires deformations, or movement, in the direction of the applied load. As with uplift, the greater the amount of passive resistance mobilized, the larger the horizontal movement required.

Two recommended foundation designs using ground anchors have been developed. One design uses ground anchors with stabilizer plates. The ground anchor/stabilizer plate design is similar to a "standard set," but includes additional aspects required to resist flood forces and flood damage.

The second ground anchor design has been developed using ground anchors installed for axial (in-line) loading. In-line anchors offer superior performance to anchors used with stabilizer plates because fewer are needed for the same level of performance. More importantly, in-line anchors are less prone to becoming loose and can withstand repeated loading better than anchors with stabilizer plates. One consideration of in-line anchors is that they need to be installed prior to home placement. This requires additional advanced planning of home placement and also requires using installers with experience in the use of in-line anchors.

10.2 Summary of Recommended Foundations

A summary and a comparison of the six different recommended foundation systems proposed in this guide are given in Table 10-1.

Table 10-1. Summary of Recommended Foundations

Type of Foundation	Advantages	Disadvantages
Reinforced masonry (M-1 to M-4)	• Little or no maintenance	• Need crane to set home • Expensive • Need custom feature built into home to accommodate foundation wall • Shear reinforcement needed
Wood framed (WF-1 to WF-4)	• No crane installation necessary	• Kbba j lafa`^qflk ql el j b ql accommodate foundation wall • Shear reinforcement needed
Braced masonry pier (BM-1.1 to BM-2.2)	• Typical installation methods	• Adjustment of straps needed after a design event
Wood H-frame (HF-1.1 to HF-2.2)	• Uses common materials • Easily adapted to site conditions	• Need crane to set home • Amount of work under home • Accurate placement of vertical posts at concrete footings

Table 10-1. Summary of Recommended Foundations (continued)

Type of Foundation	Advantages	Disadvantages
Ground anchors with stabilizer plate (GASP-90-1.1 to GASP-110/130/150-2.2)	• Inexpensive • Readily available • Easy to install • Anchors installed after home is in place	• Not as strong as typical foundation • Human intervention needed after a design event • Home likely to move during a design event • Home may need to be lifted and re-centered on foundation
Ground anchor – in-line (GA-90-1.1 to GA-110/130/150-2.2)	• Better performance than anchors with stabilizer plate – uses fewer • Anchors readily available	• Adjustment of straps after a design event • Anchors need to be accurately installed prior to placement of home

10.3 Floodwater Velocity Design Considerations for Pier Foundations

As is noted on the design drawings for the recommended foundations (Appendix H), the design of the pier is dependent on the floodwater velocities. There are four basic pier designs, each of which has a different design flood flow velocity. Furthermore, whether or not a single or double block design is used will also affect the design floodwater velocity. Pier designs and the corresponding recommended limit design velocities are provided in Table 10-2.

Table 10-2. Design Flood Flow Velocity for Concrete Masonry Unit Foundations[1]

Pier Construction	Dry Stack	Dry Stack with Face Mortar	Bonded Stack[2]	Fully Grouted, Reinforced, and Anchored to Concrete Foundation
Single Stack	1.00 fps[3] 1.25 fps[4]	2.00 fps	2.50 fps	5.00 fps
Double Stack	1.25 fps[5] 1.75 fps[6]	3.00 fps	3.00 fps	5.00 fps

[1] Sbil`fqfbp ^ob qeb j^uf j r j abpfdk «l la «l t clo b^`e j^plkov _il`h mfbo pe l t k+ Abpfdk sbil`fqv ^mmif`^_ib ql mfbop rm ql 03 inches high.

[2] Bonded piers use Type M or S Portland cement and lime mortar to adhere horizontal and vertical joints between block. Mlivrobqe^kb _^pba j^plkov ^aebpfsb `boqfªba _v ^ ob`ldkfwba k^qflk^i qbpqfkd ^dbk`v clo rpb fk j^plkov `lkpqor`qflk fk accordance with the IRC and IBC also may be used.

[3] Dry stack pier design velocity of 1.00 fps applies to single stack block piers supported on ABS pads.

[4] Dry stack pier design velocity of 1.25 fps applies to single stack block piers supported on concrete pad or footing

[5] Dry stack pier design velocity of 1.25 fps applies to double stack block piers supported on ABS pad

[6] Dry stack pier design velocity of 1.75 fps applies to double stack piers supported on a concrete pad or footing

Methods of determining flood velocities are presented in Appendix C.

10.4 Recommended Foundation Designs for Seismic Areas

The recommended foundation designs proposed in this chapter are designed mainly for flood and wind loadings. They are not specifically designed for seismic loadings. However, some of the designs have some seismic resisting capabilities. In Sections 10.4.1 through 10.4.3, three recommended foundation designs suitable for seismic areas are introduced. These are designs that have been included in the most recent release of *Model Manufactured Home Installation Standards* (NFPA 225) and are presented in Appendix H.

10.4.1 Concrete Masonry Pier Foundation Designs

(Drawing Numbers: SP-1/2.1 to SP-1/2.2)

This design applies to concrete masonry piers located along and attached to the chassis beams, providing both vertical and lateral force support to a manufactured home. The pier cannot be less than 16 inches square and must be supported on a concrete footing. Each concrete masonry pier must be provided with no less than two No. 4 vertical reinforcing bars located in diagonally opposite corners. Anchorage shall be provided between the support system and manufactured home that is capable of resisting the greater of the load and forces specified in *Standard on Manufactured Housing* (NFPA 501), Table SP-1.2 (Drawing SP-1/2.2), and the reactions specified by the home manufacturer.

The grouting required for pier construction will likely require homes to be crane set on this style of foundation.

10.4.2 Masonry Wall Foundation Designs

(Drawing Numbers: SM-1/2.1 to SM-1/2.2)

This design applies to foundation walls located at the manufactured home perimeter and to provide lateral force support. Foundation stem wall construction must consist of concrete or concrete masonry units supported on a continuous concrete footing. The stem cannot be less than 6 inches thick.

Each concrete or concrete masonry foundation wall must use no less than No. 4 vertical reinforcing bars at a space not exceeding 4 feet with a standard hook of not less than 8 inches in the footing. Anchorage shall be provided between the support system and manufactured home that is capable of resisting the greater of the loads and forces specified in NFPA 501, Table SM-1.1 (Drawing SM-1/2.2), and the reaction specified by the home manufacturer.

10.4.3 Wood Framed Foundation Designs

(Drawing Numbers: SWF-1/2.1 to SWF-1/2.2)

This design applies to continuous wood framed cripple walls located at the manufactured home perimeter to provide lateral force support. The continuous concrete perimeter footing cannot have a width less than 12 inches. Also, the concrete shall extend less than 8 inches above the highest adjacent grade.

When the home length exceeds 60 feet, two interior transverse shear walls with continuous footings must be added with spacing between walls not exceeding 30 feet. Access openings shall be provided at the center transverse interior footings. The height of the cripple walls shall exceed 4 feet above the top of the footing.

The concrete footing shall be provided with not less than two No. 4 horizontal reinforcing bars. Lap splice No. 4 bars no less than 24 inches straight and provide no less than 12 inches bend around corners. Anchorage shall be provided between the cripple wall and manufactured home that is capable of resisting the greater of the reaction forces specified in NFPA 225, Table 13.4.7, the reactions specified in SWF-1.1 (Drawing SWF-1/2.2), and anchorage requirements specified by the home manufacturer. If anchorage requirements from the home manufacturer are not available or if the manufactured home's weight and dimensions are not within the criteria established in these designs, anchorage requirements shall be determined by engineering analysis based on loads specified by ASCE 7.

Anchorage between the cripple wall sill plate and the concrete footing shall be provided not less than 1/2-inch diameter anchor bolts, starting with no more than 8 inches from the end of each foundation wall. Anchor bolts cannot be less than 8 inches embedded into the concrete. Also, anchor bolts shall exceed 16 inches on center for an end wall of single-wide homes, and 32 inches on center for the other walls. Each anchor bolt shall be provided with a steel plate washer dimensions of no less than 1/4 inch by 3 inch by 3 inch that has a hole diameter of 11/16 of an inch that is installed with a standard cut washer.

The wood framed perimeter design should allow the foundation to be built to the dimensions of the manufactured home; therefore, crane installation should not be required.

10.5 Design Drawings

The design drawings for this guide are listed in Table 10-3 and are contained in Appendix H.

Table 10-3. Foundation Drawings

Drawing No.	Title
GN-1.1	Recommended Foundation – General Notes
M-1	Single Unit Masonry Foundation Plan

Table 10-3. Foundation Drawings (continued)

Drawing No.	Title
M-2	Double Unit Masonry Foundation Plan
M-3	Masonry Wall Foundation Detail
M-4	End Wall Foundation Detail
WF-1	Single Unit Wood Framed Foundation Plan
WF-2	Double Unit Wood Framed Foundation Plan
WF-3	Wood Framed Foundation Detail
WF-4	Wood Framed Shear Wall Detail
BM-1.1	Single Unit Braced Masonry Pier Foundation Plan
BM-1.2	Braced Masonry Pier Detail
BM-2.1	Double Unit Braced Masonry Pier Foundation Plan
BM-2.2	Braced Masonry Pier Detail
HF-1.1	Single Unit Braced Wood H-Frame Foundation Plan
HF-1.2	Single Unit Wood H-Frame Detail
HF-2.1	Double Unit Braced Wood H-Frame Foundation Plan
HF-2.2	Double Unit Wood H-Frame Detail
GASP90-1.1	Single Unit Ground Anchor Foundation Plan
GASP90-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP90-2.1	Double Unit Ground Anchor Foundation Plan
GASP90-2.2	Ground Anchor and Pier Detail (Double Unit)
GASP110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GASP110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GASP110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
GA90-1.1	Single Unit Ground Anchor Foundation Plan
GA90-1.2	Ground Anchor and Pier Detail (Single Unit)
GA90-2.1	Double Unit Ground Anchor Foundation Plan
GA90-2.2	Ground Anchor and Pier Detail (Double Unit)
GA110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GA110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GA110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GA110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
APD-1.1	Alternative Pier Details for Flood Velocities Not Shown on Plans
AS-1.1	Lateral Ground Anchor Spacing
AS-1.2	Longitudinal Ground Anchor Spacing and Anchor Notes

Table 10-3. Foundation Drawings (continued)

Drawing No.	Title
SP-1/2.1	Single Unit Concrete Masonry Pier Foundation Plan
SP-1/2.2	Concrete Masonry Pier Details
SM-1/2.1	Single Unit Concrete Masonry Wall Foundation Plan
SM-1/2.2	Concrete Masonry Wall Foundation Detail
SWF-1/2.1	Single Unit Wood Framed Foundation Plan
SWF-1/2.2	Wood Framed Foundation Detail

A. References

American Concrete Institute, *Building Code Requirements for Masonry Structures* (ACI 530), 2008.

American Concrete Institute, *Building Code Requirements for Structural Concrete* (ACI 318) and *Commentary* (318R), 2005.

American Forest and Paper Association and American Wood Council, *National Design Specification (NDS) for Wood Construction* and *Commentary*, 2006.

American Institute of Steel Construction, *Manual of Steel Construction* (AISC 325-05, 13th Edition), 2005.

American National Standards Institute/American Institute of Steel Construction, *Specification for Structural Steel Buildings* (ANSI/AISC 360-05), 2005.

American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*, (ASCE 7-98, 7-02, and 7-05).

American Society of Civil Engineers, *Flood Resistant Design and Construction*, (ASCE 24-05).

Bowles, J.E., *Foundation Analysis and Design*, McGraw-Hill Book Company, 1977.

Code of Federal Regulations (CFR), *General Provisions* (44 CFR 59), 2004.

Code of Federal Regulations (CFR), *Criteria for Land Management and Use* (44 CFR 60), 2004.

Das, B. M., Seeley, G. R., "Breakout Resistance of Shallow Horizontal Anchors," *Journal of the Geotechnical Engineering Division*, ASCE, Vol. 101(T9), 999-103, 1975.

Das, B. M., Seeley, G. R., "Inclined Load Resistance in Sand," *Journal of the Geotechnical Engineering Division*, ASCE, Vol. 101(9), 995-998, 1975.

FEMA, *Coastal Construction Manual* (FEMA 55, 3rd Edition), June 2000 (reissued August 2005 under a new cover with no change in technical content).

FEMA, *Elevated Residential Structures* (FEMA 54), March 1984.

FEMA, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures* (FEMA 259), June 2001.

FEMA, *Homeowner's Guide to Retrofitting* (FEMA 312, 2nd Edition), 2009.

FEMA, *Installing Seismic Restraints for Mechanical Equipment* (FEMA 412), December 2002.

FEMA, *Managing Floodplain Development in Approximate A Zone Areas, A Guide for Obtaining and Developing Base (100-year) Flood Elevations,* (FEMA 265), July 1995.

FEMA, *Mitigation Assessment Team Report: Hurricane Ike in Texas and Louisiana, Building Performance Observations, Recommendations, and Technical Guidance* (FEMA P-757), April 2009.

FEMA, *Mitigation Assessment Team Report: Hurricane Ivan in Alabama and Florida, Observations, Recommendations, and Technical Guidance* (FEMA 489), August 2005.

FEMA, *Mitigation Planning How-to Guides* (FEMA 386), May 2005.

FEMA, *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (FEMA 450), 2003 Edition.

FEMA, *Protecting Building Utilities from Flood Damage* (FEMA 348), November 1999.

FEMA, *Taking Shelter From the Storm: Building A Safe Room for Your Home or Small Business* (FEMA 320, 3rd Edition), August 2008.

FEMA, Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas in accordance with the National Flood Insurance Program*, August 2008.

FEMA, Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program*, August 2008.

FEMA, Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program*, August 2008.

FEMA, Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program*, August 2008.

FEMA, Technical Bulletin 10-01, *Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe from Flooding in accordance with the National Flood Insurance Program*, May 2001.

Federal Manufactured Housing Consensus Committee (MHCC), *Model Manufactured Home Installation Standards*, 2003 Edition.

Geddes, J.D., Murray, E.J. "Passive Inclined Anchorages in Sand," *Journal of Geotechnical Engineering*, ASCE, Vol. 117 (5), 810-814. 1991.

Ghaly, A.M., Hanna, A., Hanna, M. "Uplift Behavior of Screw Anchors in Sand I: Dry Sand," *Journal of Geotechnical Engineering*, ASCE, Vol. 117 (5), 773 – 783. 1991.

Ghaly, A.M., Hanna, A., Hanna, M. "Uplift Behavior of Screw Anchors in Sand II: Hydrostatic and Flow Conditions," *Journal of Geotechnical Engineering*, ASCE, Vol. 117 (5), 784 – 808. 1991.

Ghaly, A.M., Clemence, S.P. "Pullout Performance of Inclined Helical Screw Anchors in Sand," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 124(7), 617-627. 1998.

FHWA NHI 01-001, *Evaluating Scour at Bridges,* 4th Edition, May 2001, Hydraulic Engineering Circular No. 18.

International Code Council, Inc. (ICC), *International Residential Code 2009*, Falls Church, VA. 2009.

International Council of Building Officials (ICBO), *Acceptance Criteria for Expansion Anchors in Concrete and Masonry Elements* (AC01), July 1991.

Longinow, A., *Guidance for Support of Manufactured Housing and Other Relocatable Structures* for the Idaho Bureau of Disaster Services, for FEMA, under the National Earthquake Technical Assistance Contract EMW-92-C-3852, Task #45, June 22, 1995.

Longinow, A., Meinheit D. F., and Pearson, J. F., *Laboratory Testing of Soil Anchors* for the U.S. Department of Housing and Urban Development, Washington, DC, WJE No. 931299, December 15, 1994.

Manufactured Housing Research Alliance (MHRA), *Guide to Foundation and Support Systems for Manufactured Homes*, March 2002.

Marshall, Richard D., *Manufactured Homes – Probability of Failure and the Need for Better Windstorm Protection Through Improved Anchoring Systems*, United States Department of Commerce, National Institute of Standards and Technology, November 1994.

Marshall, Richard D., and Yokel, Felix Y., *Recommended Performance-Based Criteria for the Design of Manufactured Home Foundation Systems to Resist Wind and Seismic Loads* (NISTIR 5664), U.S. Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD, August 1995.

Marshall, Richard D., *Wind Load Provisions of the Manufactured Home Construction and Safety Standards – A Review and Recommendations for Improvement*, United States Department of Commerce, National Institute of Standards and Technology, May 1993.

National Fire Protection Association (NFPA), *Building Construction and Safety Code*, (NFPA 5000), Quincy, MA, 2009.

National Fire Protection Association (NFPA), *Model Manufactured Home Installation Standard*, (NFPA 225), Quincy, MA, 2009.

National Fire Protection Association (NFPA), *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*, (NFPA 501A), Quincy, MA, 2009.

National Fire Protection Association (NFPA), *Standard on Manufactured Housing*, (NFPA 501), Quincy, MA, 2005.

Peck, R.A., Hanson, W.E., and Thornburn, T.H., *Foundation Engineering*, Second Edition, John Wiley & Sons, Inc., 1973.

Pearson, John E., Longinow, Anatol, and Meinheit, Donald F., "Wind Protection Tie-Downs for Manufactured Homes," *Practice Periodical on Structural Design and Construction*, 1996.

State of California, Department of Housing and Community Development, *The Effectiveness of Manufactured Home Support Systems During Earthquakes*, April 1992.

State of California, Department of Housing and Community Development, Division of Codes and Standards, *Manufactured Homes: A Handbook for Local Government*, July 2001.

Systems Building Research Alliance, *Guide to Foundation and Support Systems for Manufactured Homes*. 2002.

United States Code (USC), *The National Manufactured Housing Construction and Safety Standards Act of 1974*, (42 USC 5404, Section 605).

U.S. Army Corps of Engineers, *Shore Protection Manual*, 4th Edition. 1984.

U.S. Department of Housing and Urban Development, *The Effect of Earthquakes on Manufactured Home Installation* (HUD-7004), December 1995.

U.S. Department of Housing and Urban Development, NAHB Research Center, *Factory and Site-Built Housing: A Comparison for the 21st Century*, October 1998.

U.S. Department of Housing and Urban Development, NAHB Research Center, *Manual for the Construction of Residential Basements in Non-Coastal Flood Environs* (CR-997), March 1977.

U.S. Department of Housing and Urban Development, *Manufactured Home Construction and Safety Standards* (24 CFR Part 3280), 1999.

U.S. Department of Housing and Urban Development, *Manufactured Home Producer's Guide to the Site-Built Market*, May 2000.

U.S. Department of Housing and Urban Development, *Minimizing Damage and Repair Costs to Manufactured Homes During an Earthquake*, February 1996.

U.S. Department of Housing and Urban Development, *Model Manufactured Home Installation Standards* (24 CFR 3285), 2008.

U.S. Department of Housing and Urban Development, *Northridge Earthquake Effect on Manufactured Housing in California* (HUD-0006466), Prepared by the NAHB Research Center, Inc., June 1994.

U.S. Department of Housing and Urban Development, Office of Policy Development and Research, *Permanent Foundations Guide for Manufactured Housing* (HUD-007487), September 1996.

U.S. Department of Housing and Urban Development, Office of Policy Development and Research, *Residential Structural Design Guide: 2000 Edition*, Prepared by the NAHB Research Center, Inc., February 2000.

U.S. Department of Transportation, Federal Highway Administration, *Evaluating Scour at Bridges, 4th Edition* (FHWA NHI 01-001), Hydraulics Engineering Circular No. 18, May 2001.

Yokel, F. Y. "A Study of Reaction forces on Mobile Home Foundations by Wind and Flood Loads." *NBS Building Science Series 132*. U.S. Department of Commerce, National Bureau of Standards, Washington, DC, 1981.

B. Sources for Flood Information

To develop an effective manufactured home installation strategy applicable to a flood hazard area, several hydrological factors must be evaluated. These include the regulatory floodplain boundaries and the anticipated flooding characteristics for the site, such as location of the floodway, depth, velocity, duration, rate-of-rise, and frequency. Various sources for this information are available. Also, there are methods by which portions of such information can be individually developed.

As part of the NFIP, FEMA develops FIS reports that contain the most current and detailed information available for a community. Such studies can include a FIRM and a Flood Boundary and Floodway Map (FBFM). Although studies completed prior to 1986 are no longer separate from FIRMs, many communities still have pre-1986 studies and an FIS report from which the following information can be obtained:

- Floodplain and floodway boundaries
- Stream profiles that show the elevations of the 100-year or "base flood" (a flood that has a 1-percent chance of being equaled or exceeded in any given year) and other flood events
- Mapped base flood elevations that can be used to develop flood depths for a specific site in combination with other data
- Flood velocity data
- Flood frequency data
- Flood discharge data
- Historical flood information

FIS reports can be extremely valuable sources for much of the information necessary to evaluate a potential manufactured home site. The specific hydrologic data elements, and ways to obtain them, are described below.

B.1 Map Modernization and Risk Mapping, Assessment, and Planning (Risk MAP)

FEMA developed a plan in 1997 to modernize the FEMA flood mapping program. The plan outlined the steps necessary to update FEMA's flood maps for the nation to digital format and streamline FEMA's operations in raising public awareness of the importance of the maps and responding to requests for revision. Since 1997, the plan has continually evolved as new

products, processes, and technical specifications have been developed and implemented within current funding levels. The goal of FEMA's Map Modernization Plan is to upgrade the 100,000 panel flood map inventory by the following methods:

- Develop up-to-date flood hazard data for all flood-prone areas nationwide to support sound floodplain management and prudent flood insurance decisions
- Provide the maps and data in digital format to improve the efficiency and precision with which mapping program customers can use this information
- Fully integrate FEMA's community and State partners into the mapping process to build on local knowledge and efforts
- Improve processes to expedite creating and updating the maps
- Improve customer services to speed processing of flood map orders and raise public awareness of flood hazards

Building on the Map Modernization Program, FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) is a seamless program aimed at reducing losses of life and property through effective local mitigation activities enabled by quality flood hazard data, risk assessments, and mitigation planning. Risk MAP will provide an integrated national assessment of risks based on digital flood hazard data and web-accessible data. Risk MAP information and tools will help communities develop informed mitigation plans that will reduce losses from natural hazards.

The goals of Risk MAP are:

- Flood Hazard Data: Address gaps in flood hazard data to form a solid foundation for risk assessments, floodplain management, and actuarial soundness of the National Flood Insurance Program.
- Public Awareness/Outreach: Ensure that a measurable increase of the public's awareness and understanding of risk results in a measurable reduction of current and future vulnerability.
- Hazard Mitigation Planning: Lead and support State, Local, and Tribal communities to effectively engage in risk-based mitigation planning resulting in sustainable actions that reduce or eliminate risks to life and property from natural hazards.
- Enhanced Digital Platform: Provide an enhanced digital platform that improves management of Risk MAP and also improves communication and sharing of risk data and related products to all levels of government and the public.
- Alignment and Synergies: Align Risk Analysis programs and develop synergies to enhance decision-making capabilities through effective risk communication and management.

B.2 Flood Study Software Programs

FEMA has approved the use of several modeling programs to support the NFIP and flood hazard mapping. These programs were created by various agencies and organizations, including the

U.S. Natural Resources Conservation Service (NRCS), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and FEMA mapping contractors. Information about approved software is available at the FEMA website at http://www.fema.gov/plan/prevent/fhm/frm_soft.shtm. The models can be organized into several categories:

Nationally Accepted Models

- **Coastal Models:** coastal storm surge, coastal wave height, and coastal wave effect models, including FEMA Surge, AdCIRC, WHAFIS 3.0, and RUNUP 2.0.
- **Hydrologic Models:** single event, continuous event, and interior drainage analysis models, including HEC-1, HEC-HMS, and TR-20.
- **Hydraulic Models:** one-dimensional steady flow, one-dimensional unsteady flow, two-dimensional steady/unsteady flow, and floodway analysis models, including HEC-RAS, HEC-2, and WSPRO.

Coastal model outputs include stillwater elevations (FEMA Surge and AdCIRC), wave height profiles along a transect (WHAFIS 3.0), and wave run-up elevations (RUNUP 2.0). Hydrologic model outputs are generally discharge values. Hydraulic model outputs include floodway analyses (where applicable) and flood elevations for 10-, 2-, 1-, and 0.2-percent exceedance probability floods.

Locally Accepted Models

- **Hydrologic Models:** single event models
- **Hydraulic Models:** one- and two-dimensional unsteady flow models

The FEMA website also provides guidance on the use of automated hydrologic and hydraulic (H&H) techniques as part of the NFIP Map Modernization efforts at http://www.fema.gov/plan/prevent/fhm/mm_main.shtm.

B.3 Flood Hazard Boundaries

Flood hazard boundaries must be identified for the different degrees and types of flooding, including floodways, floodway fringe areas, coastal high hazard areas, coastal fringe areas, and shallow flooding areas. These boundaries are significant for determining the specific flood hazard zones that would be part of a proposed development site and, thereby, influence site development. In addition, boundaries indicate where floodplain management regulations and flood insurance requirements apply. Flood hazard boundary data can be obtained from FBFMs, FIRMs, and floodplain maps, or can be developed from topographic maps, zoning maps, aerial photographs, and related hydrologic data.

B.4 Flood Depth

Flood depths are determined by the difference between water surface elevations at times of flooding and normal ground surface elevations. This information is important both in determining the elevations at which floodwaters will likely cause damage and in defining the appropriate elevations for flood insurance and floodplain management regulations. Flood depths also influence the hydrostatic forces in effect during flooding, including the horizontal loads that can cause lateral displacement or overturning and the vertical loads that can cause uplift and flotation. Therefore, it is important to know the flood depth to determine appropriate foundations for the site.

Flood depths for a particular site can be derived using a FIRM showing BFEs in combination with a topographic map depicting ground elevations. Flood depth data are also available from various technical studies that include flood elevations, water surface profiles, or stream and coast cross-sections. In the absence of official reports, information on flood depths can be obtained from site surveys and historical records.

B.5 Floodwater Velocity

The average and maximum velocity of floodwater determines the hydrodynamic forces that influence horizontal loads in excess of hydrostatic loads. Velocity also affects the magnitude of debris impact loads (i.e., force of flotation objects carried by floodwaters), and can increase erosion and affect soil stability on slopes. Data on water velocity are listed in Floodway Data Tables and are often included in FIS reports. Data might also be available from various floodplain technical studies or determined by special hydrological studies. FIS Floodway Data Tables include the mean velocity of floodwaters (for the base flood event) within the floodway. These mean velocities can be used to estimate the upper limit of floodwater velocity in the adjacent flood fringe portion of the floodplain.

Velocity can also be calculated by assuming floodwaters are at a uniform flow, estimating some floodplain characteristic, and using Manning's Equation:

$$V = \left(\frac{k}{n}\right)\left(\frac{A}{P}\right)^{2/3}(S)^{1/2}$$

Where: V = Average flow velocity (fps)

k = 1.49, unit conversion

A = Cross-sectional flow area (square feet) (shaded area, Figure B-1)

P = Wetted perimeter of A (feet) (labeled in Figure B-1)

$\left(\frac{A}{P}\right)$ = Hydraulic radius (feet)

S = Gradient (feet/feet) (use average ground surface slope within a reach from approximately 0.5 mile upstream to approximately 0.5 mile downstream)

n = Manning's channel roughness coefficient, empirical value developed through lab testing of flow through a pipe

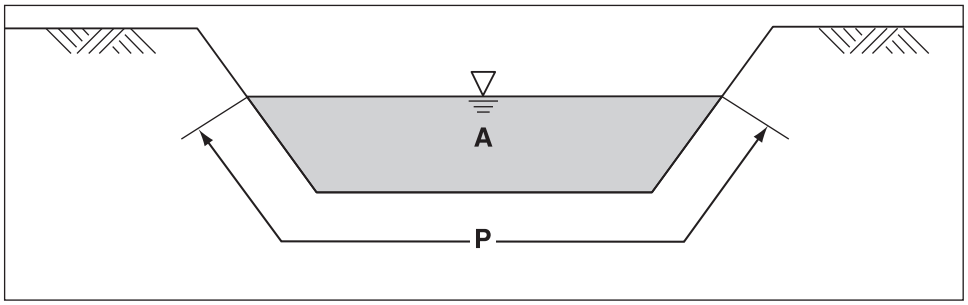


Figure B-1. Stream cross-section for Manning's Equation

B.6 Frequency

Frequency of flooding is a major consideration in evaluating potential installation sites. Frequency of flooding is the probability (in percent) that a random flood event will equal or exceed a specified magnitude in a given time period. Manufactured homes sited at lower elevations near a flooding source will likely have higher frequency of flooding than those located at higher elevations. Flood frequency information is included in FIS reports and other technical floodplain studies. Frequency of flooding can also be statistically determined using historical records.

If manufactured homes are installed on sites vulnerable to high frequency floods (i.e., floods that occur often), there is a greater risk of damage and there will be a need for more frequent evacuations. Not only do frequent evacuations present an increased risk to owners and/or tenants, but also to a community's emergency management officials who provide assistance during evacuations.

B.7 Rate of Rise

The rate of rise is how rapidly water depth increases during a flooding event. This factor is important in evaluating buoyancy hazards and investigating the feasibility of an evacuation plan. The rate can be derived from a stream flow hydrograph that compares flooding depth to time for the area under consideration. Determining the rate of rise requires information that may be obtained from existing hydrological studies, on-site investigations, historical records, and nearby gauge records.

B.8 Duration

The duration of a flood is a function of the rate of rise and fall of water. Duration influences the saturation of soils and building materials, the amount of seepage, and the length of time that a

manufactured home might be inaccessible. Various floodplain technical studies and historical records are sources of information concerning duration of flooding.

B.9 Sources of Information

Tables B-1 and B-2 provide sources of various types of information and assistance.

Table B-1. Floodplain Management Information

Floodplain Agencies	Data Type							
	Ci l lamol l ªkd Fkc l o j ^qf l k	Preserve Channel Capacity	Development Regulations	Land Use Controls	Floodwater Control	Public Information	Post-Flood Relief	Flood Warning System
Federal Emergency Management Agency	■		■		■	■	■	
U.S. Army Corps of Engineers	■	■	■		■	■	■	■
Natural Resources Conservation Service	■	■			■		■	
Department of Housing and Urban Development			■				■	
National Oceanic and Atmospheric Administration					■			■
U.S. Geological Survey					■			
Federal Highway Administration		■			■	■		
State Floodplain Management Coordinating Agency	■	■	■	■	■			
Regional Authorities	■	■	■		■	■	■	
Local Government Planning Agencies			■	■	■			

Table B-2. Summary of Hydrologic Data Sources

Agencies	Data Type															
	Coastal Surveys and Reports	Flood Control Measures	Flood Boundary Maps	Flood Insurance Rate Maps	Floodplain Information Reports and Technological Studies	Flood Records and Probabilities	Hydrologic Atlases	National Flood Insurance Program Regulations	State Floodplain Regulations	Technical Assistance	Topographic Maps	Zoning Ordinances and Maps	Coastal Modeling Software	Hydrologic Modeling Software	Statistical Modeling Software	Hydraulic Modeling Software
Federal Emergency Management Agency	■	■	■	■				■		■			■	■	■	
U.S. Army Corps of Engineers	■	■	■	■	■	■				■	■	■	■	■	■	■
National Resources Conservation Service		■			■	■								■		
National Oceanic and Atmospheric Administration	■				■	■							■	■		
U.S. Geological Survey					■	■	■				■			■	■	■
State Floodplain Management Coordinating Agency	■	■	■	■		■		■	■	■						
Regional Authorities (e.g., Tennessee Valley Authority)		■			■	■				■	■			■		
Local Government Planning Agency or Municipal Engineer	■	■	■	■	■	■		■	■	■	■	■	■	■		■

C. Flood Velocity Determination

C.1 Velocity Data

Determining the design floodwater velocity (velocity associated with base flooding) is important to properly design manufactured home foundations. Only hydraulic modeling or measurements from historic events can produce actual estimated velocity values. In addition to those resources, this section presents some of the tools and sources of information available that can help to provide an estimate of the floodwater velocity.

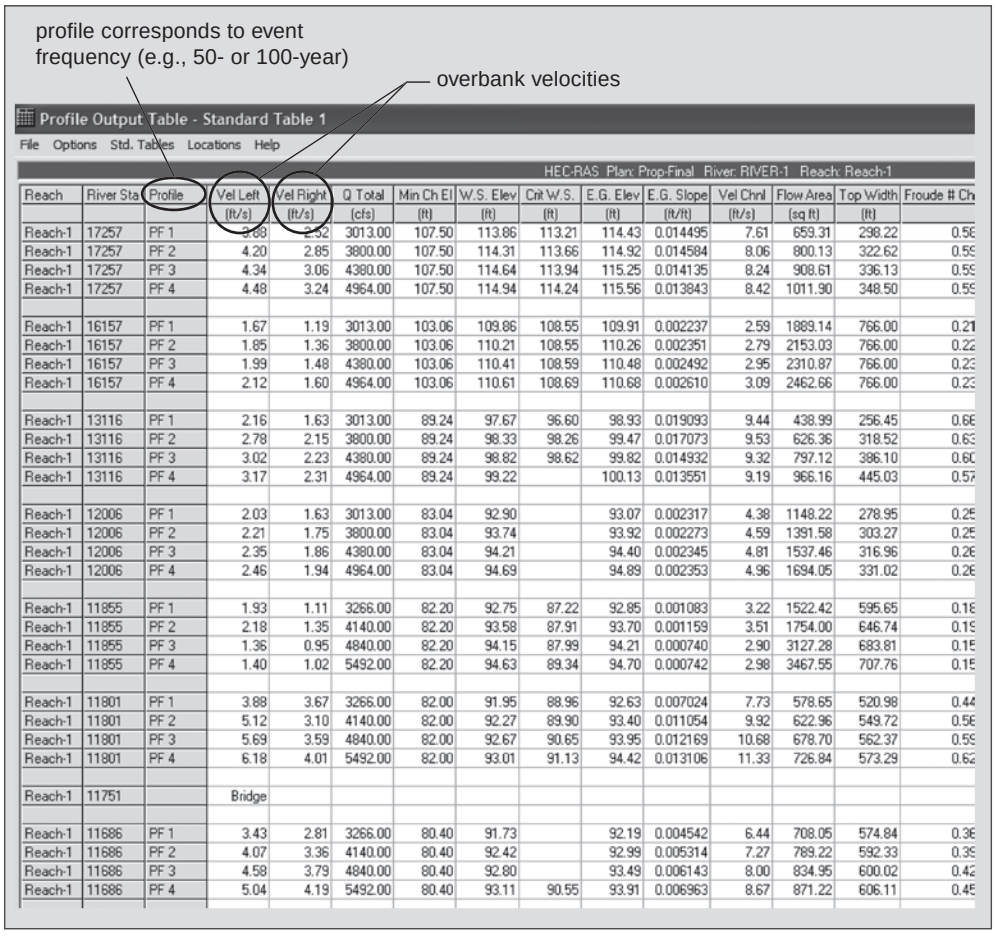
C.1.1 Hydraulic Modeling

Hydrologic and hydraulic (H&H) modeling is done as part of floodplain mapping. Through hydraulic models such as the USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS), riverine systems are modeled to determine the elevation of a given flood, such as the base flood, and the extent of flooding. Hydraulic modeling tools also provide additional helpful information about flood scenarios, including average channel and overbank floodwater velocities at particular cross-section locations. These velocities can be used as design velocities for structures when they correspond to a cross-section at or very near the development site. Figure C-1 shows an example of output from a HEC-RAS model run that includes overbank velocities. While these data can be very helpful, communities are expected to use the best available data, and overbank flood velocities may not be readily available in FIS reports.

Generally, the most easily accessible tool to use in estimating velocities will be the community's FIS. As described in Section 5.2.4, mean floodway velocities are determined during hydraulic modeling and can be obtained from the FIS using the following 3-step process:

- Step 1: Locate the manufactured housing site on the FIRM or DFIRM. This first step is illustrated in Figure C-2 using an example DFIRM.
- Step 2: Locate the stream cross-section on the FIRM or DFIRM that is located closest to the manufactured housing site. This second step is illustrated in Figure C-3 using an example DFIRM.
- Step 3: Match the cross-section for a particular stream on the FIRM or DFIRM with the cross-section in the stream's Floodway Data Table found in the FIS. This third step is illustrated in Figure C-4 using an example Floodway Data Table. At cross-section A, the mean floodway velocity is 0.4 fps.

It is important to note that the floodway's mean velocity is not a good measure of the actual flood velocity within the flood fringe, but it can be used as a general measure to determine



Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Prop-Final River: RIVER-1 Reach: Reach-1

Reach	River Sta	Profile	Vel Left	Vel Right	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Ch
			(ft/s)	(ft/s)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	17257	PF 1	3.68	2.52	3013.00	107.50	113.86	113.21	114.43	0.014495	7.61	659.31	298.22	0.58
Reach-1	17257	PF 2	4.20	2.85	3800.00	107.50	114.31	113.66	114.92	0.014584	8.06	800.13	322.62	0.59
Reach-1	17257	PF 3	4.34	3.06	4380.00	107.50	114.64	113.94	115.25	0.014135	8.24	908.61	336.13	0.59
Reach-1	17257	PF 4	4.48	3.24	4964.00	107.50	114.94	114.24	115.56	0.013843	8.42	1011.90	348.50	0.59
Reach-1	16157	PF 1	1.67	1.19	3013.00	103.06	109.86	108.55	109.91	0.002237	2.59	1889.14	766.00	0.21
Reach-1	16157	PF 2	1.85	1.36	3800.00	103.06	110.21	108.55	110.26	0.002351	2.79	2153.03	766.00	0.22
Reach-1	16157	PF 3	1.99	1.48	4380.00	103.06	110.41	108.59	110.48	0.002492	2.95	2310.87	766.00	0.23
Reach-1	16157	PF 4	2.12	1.60	4964.00	103.06	110.61	108.69	110.68	0.002610	3.09	2462.66	766.00	0.23
Reach-1	13116	PF 1	2.16	1.63	3013.00	89.24	97.67	96.60	98.93	0.019093	9.44	438.99	256.45	0.68
Reach-1	13116	PF 2	2.78	2.15	3800.00	89.24	98.33	98.26	99.47	0.017073	9.53	626.36	318.52	0.63
Reach-1	13116	PF 3	3.02	2.23	4380.00	89.24	98.82	98.62	99.82	0.014932	9.32	797.12	386.10	0.60
Reach-1	13116	PF 4	3.17	2.31	4964.00	89.24	99.22		100.13	0.013551	9.19	966.16	445.03	0.57
Reach-1	12006	PF 1	2.03	1.63	3013.00	83.04	92.90		93.07	0.002317	4.38	1148.22	278.95	0.25
Reach-1	12006	PF 2	2.21	1.75	3800.00	83.04	93.74		93.92	0.002273	4.59	1391.58	303.27	0.25
Reach-1	12006	PF 3	2.35	1.86	4380.00	83.04	94.21		94.40	0.002345	4.81	1537.46	316.96	0.26
Reach-1	12006	PF 4	2.46	1.94	4964.00	83.04	94.69		94.89	0.002353	4.96	1694.05	331.02	0.26
Reach-1	11855	PF 1	1.93	1.11	3266.00	82.20	92.75	87.22	92.85	0.001083	3.22	1522.42	595.65	0.18
Reach-1	11855	PF 2	2.18	1.35	4140.00	82.20	93.58	87.91	93.70	0.001159	3.51	1754.00	646.74	0.19
Reach-1	11855	PF 3	1.36	0.95	4840.00	82.20	94.15	87.99	94.21	0.000740	2.90	3127.28	683.81	0.15
Reach-1	11855	PF 4	1.40	1.02	5492.00	82.20	94.63	89.34	94.70	0.000742	2.98	3467.55	707.76	0.15
Reach-1	11801	PF 1	3.88	3.67	3266.00	82.00	91.95	88.96	92.63	0.007024	7.73	578.65	520.98	0.44
Reach-1	11801	PF 2	5.12	3.10	4140.00	82.00	92.27	89.90	93.40	0.011054	9.92	622.96	549.72	0.56
Reach-1	11801	PF 3	5.69	3.59	4840.00	82.00	92.67	90.65	93.95	0.012169	10.68	678.70	562.37	0.59
Reach-1	11801	PF 4	6.18	4.01	5492.00	82.00	93.01	91.13	94.42	0.013106	11.33	726.84	573.29	0.62
Reach-1	11751		Bridge											
Reach-1	11686	PF 1	3.43	2.81	3266.00	80.40	91.73		92.19	0.004542	6.44	708.05	574.84	0.36
Reach-1	11686	PF 2	4.07	3.36	4140.00	80.40	92.42		92.99	0.005314	7.27	789.22	592.33	0.39
Reach-1	11686	PF 3	4.58	3.79	4840.00	80.40	92.80		93.49	0.006143	8.00	834.95	600.02	0.42
Reach-1	11686	PF 4	5.04	4.19	5492.00	80.40	93.11	90.55	93.91	0.006963	8.67	871.22	606.11	0.45

Figure C-1. Example HEC-RAS output.

cross-section locations within the floodplain where floodwaters will move relatively faster or slower, and to provide an upper limit for velocities in the flood fringe.

Hydraulic modeling with the potential to provide overbank flood velocities might also be available. Modeling used to complete a community's FIS can be ordered through FEMA's Project Library by completing a FIS data request form (http://www.fema.gov/plan/prevent/fhm/st_order.shtm). These data are usually, but not always, available for communities with existing FISs. Depending on the data format (e.g., paper, diskettes, or microfiche), it may be possible to determine overbank velocities at cross-sections without significant effort. While this modeling can be helpful, the community is not expected to use it to create any new data; use of the best available data is all that is necessary. However, there is a possibility that this modeling will be available locally, perhaps through the municipal engineer, especially if new or updated modeling for the FIS has been recently completed.

H&H modeling might also be available regionally or locally if other agencies have done studies. Table 5-1 lists several Federal, State, and local agencies that might have information about past flooding events. These same agencies are the ones most likely to have performed flood studies, separate from the communities' FIS reports, for a localized area. Such studies might be performed in order to further characterize flooding in a particularly vulnerable area or to

provide updated information about an area that may have experienced significant development since the FIS was completed.

C.1.2 Documented Historic Information

Another potential source of documented floodwater velocities are post-flood reports. Refer to Table 5-1 for Federal, State, and local agencies that often publish post-event flood information. Such documentation might include information about observed damages, flood elevations, and other flood characteristics, including floodwater velocities. One such example of these types of reports is the Delaware Geologic Survey (http://www.udel.edu/dgs/index.html) Open File Reports completed after coastal storms in 1992 and 1998. These reports provide synopses of the events, high water mark survey results, rainfall and stream gauge records, and wave height records. Another example is The South Florida Water Management District, which offers reports documenting past flood events via its website (http://www.sfwmd.gov). Additionally, the Harris County (Texas) Flood Control District provides a summary of past flooding, including observed damages noting areas that were hardest hit, on their website (http://www.hcfcd.org). Local officials (e.g., engineers, floodplain managers, building inspectors, planners) are probably the best resource for determining if these types of reports exist and where they can be found.

One agency listed in Table 5-1, the U.S. Geological Survey (USGS), measures stream flow characteristics at established gauges throughout the U.S. during flood events. The specific characteristics measured depend on the gauge's capabilities, but can include discharge and mean channel velocity. These data are available at the USGS website via the National Water Information System (NWIS) Web Water Data system (http://waterdata.usgs.gov/nwis). The USGS also frequently takes measurements of depth and velocity at discrete cross-section locations along gauged streams during flood events. This information is not available online, but can be obtained from the appropriate USGS office.

C.2 Alternate Methodologies for Estimating Velocities

In the absence of hard data such as those found in stream modeling or historic measurements and reports, local expertise and evaluation of site indicators can be used to determine relative velocities. To estimate site floodwater velocities, local officials, such as engineers and floodplain managers, with knowledge of past flood events can be consulted. Additionally, there are some site indicators that local officials can use to estimate relative velocities.

C.2.1 Knowledge of Past Flooding

Local floodplain management and building officials are encouraged to use their knowledge of past flood events and exercise their judgment in determining relative flood velocities in the absence of hard data. Some questions to consider include the following:

- Have base flood conditions consisted of very shallow (less than 1 foot) or ponding (slow draining, no velocity) flooding?

If the answer to this question is yes, then a pier foundation with dry-stacked blocks would be appropriate. With no velocity and/or very shallow floodwaters, the stability and strength provided by either surface bonded mortar or grouted/rebar/anchored piers may not be necessary.

- Have structures at or near the site been damaged by high velocity flows in the past?

  If there are any indications that high velocity floodwaters have caused damage to structures in the past, none of the pre-engineered foundations described in Appendix H should be used. Some examples of foundation failure as the result of high velocity floodwaters include: 1) structures shifting from their foundations (sliding failure), 2) scour occurring at the foundation, and 3) uplift of the structure from the foundation (in conjunction with buoyancy forces). Section 5.2.4 provides further information on hydrodynamic forces and foundation failure.

- Have moving floodwaters damaged appurtenant structures such as decks and porches?

  Floodborne debris often consists of lumber and other pieces of decking and porches. High velocity floodwaters damage attachments, such as carports, decks, porches, and awnings, and/or their connections and can lead to structural failure of the attachment. Field observations have noted that the primary cause of this failure has been inadequate support; the attachments' support systems were simply not designed or constructed to withstand the hydrodynamic loadings imposed upon them. At or near sites where appurtenant structures have been severely damaged or destroyed by fast moving floodwaters, only designs for high velocity foundations (not Appendix H foundations) should be used.

C.2.2 Site Indicators

Another set of tools to use in estimating relative velocity are characteristics of the site and/or the surrounding watershed. These indicators provide a broader frame of reference for estimating relative velocities.

The proximity of a site to the flood source (stream or river) is one of the most basic gauges of floodwater velocity. Generally, the velocity of floodwater will decrease from the channel center out to the edges of the flood fringe as illustrated in Figure C-5. The floodway is the area of the stream where floodwaters are likely to be the deepest and have the highest velocities. Therefore, in the outer edges of the flood fringe, velocities can be expected to be relatively low. Sites located well within the flood fringe closer to the floodway will tend to have higher floodwater velocities. Figure C-6 shows an aerial view of a stream with the floodway highlighted in dark gray and the floodplain outlined in white. Within the floodway, velocities will be higher. As you move outwards to the edges of the flood fringe, velocities will decrease.

Figure C-2. Manufactured housing site location on DFIRM.

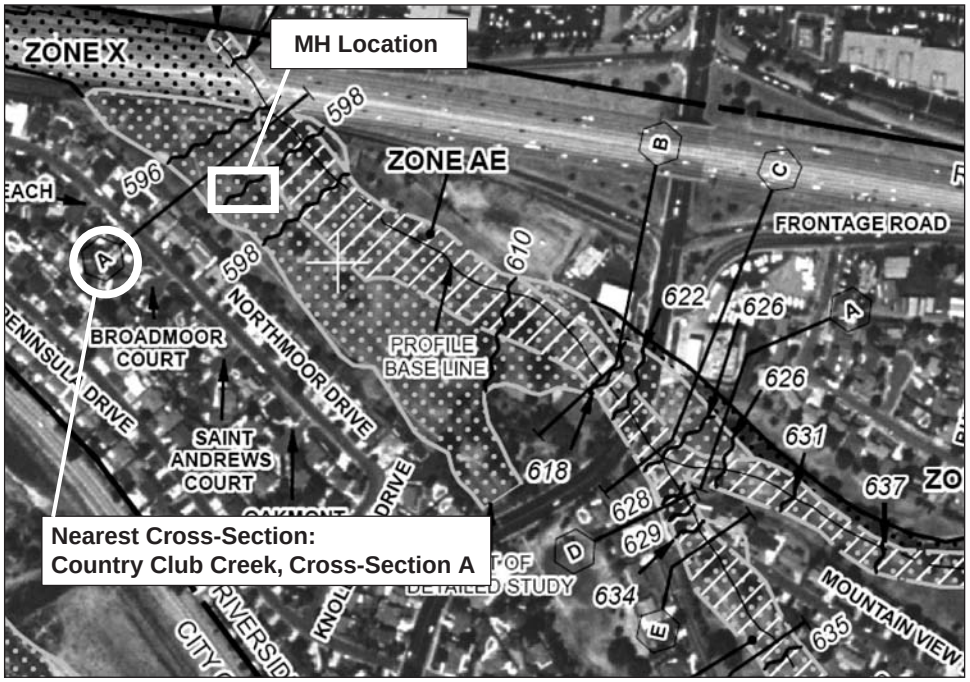


Figure C-3. DFIRM detail showing stream cross-section located closest to the manufactured housing site location.

Figure C-4. Floodway Data Table and mean velocity.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Country Club Creek								
A	800[1]	100	2,210	0.4	596.5	596.5	597.5	1.0
B	2,020[1]	70	170	1.9	617.4	617.4	618.4	1.0
C	2,250[1]	80	360	1.9	625.6	625.6	626.6	1.0
D	2,430[1]	30	83	4.8	628.6	628.6	629.6	1.0
E	2,590[1]	100	700	0.6	634.0	634.0	635.0	1.0
F	2,940[1]	70	140	2.9	634.3	634.3	635.3	1.0
G	3,640[1]	30	71	5.2	648.8	648.8	649.8	1.0
H	5,120[1]	60	122	2.9	702.0	702.0	703.0	1.0
I	5,900[1]	30	78	4.5	740.5	740.5	741.5	1.0
Country Club Creek North Tributary								
A	180[2]	30	69	5.8	626.1	626.1	627.1	1.0
B	1,520[2]	20	46	8.7	652.4	652.4	653.4	1.0
C	3,160[2]	20	53	7.0	701.7	701.7	702.7	1.0
D	3,310[2]	110	760	0.5	711.4	711.4	712.4	1.0
E	3,860[2]	50	104	3.5	716.8	716.8	717.8	1.0
Day Creek								
A	600[3]	220	1,813	4.6	639.1	639.1	640.1	1.0
B	1,070[3]	300	1,713	4.8	640.5	640.5	641.5	1.0
C	1,600[3]	380	2,339	3.6	644.2	644.2	645.2	1.0
D	2,300[3]	430	1,207	8.3	649.0	649.0	650.0	1.0
E	2,800[3]	600	2,346	3.7	653.4	653.4	654.4	1.0

[1] Feet Above Limit of Detailed Study
[2] Feet Above Confluence With Country Club Creek
[3] Feet Above Point 120 Feet Downstream of Lucretia Avenue

Mean Floodway Velocity at Cross-Section A: 0.4 fps

TABLE 7

FEDERAL EMERGENCY MANAGEMENT AGENCY

RIVERSIDE COUNTY, CA AND INCORPORATED AREAS

FLOODWAY DATA

COUNTRY CLUB CREEK – COUNTRY CLUB CREEK NORTH TRIBUTARY – DAY CREEK

Figure C-5. Flood velocity profiles.

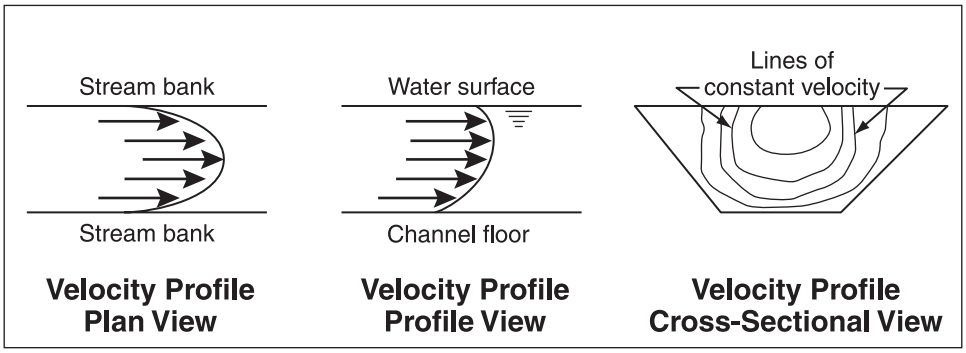


Figure C-6. Floodwaters in the floodway (dark gray) will have higher velocities than those in the flood fringes (between black and gray).

Terrain characteristics can also help to provide some clues about floodwater velocities. Flood velocity is largely dependent on the slope and roughness of the stream channel and overbank terrain. Water moves downstream faster when the channel and overbank areas are steeply sloped. Water also flows faster over paved or smooth surfaces such as roadways or parking lots as opposed to densely vegetated stream banks. Streams in steep or mountainous areas tend to have higher floodwater velocities capable of more damage than those in flatter areas. Figure C-7 shows a damaged home along a stream that is surrounded by steep, mountainous terrain and subject to flash flooding.

Figure C-7. Home damaged along a stream subject to flash flooding due to surrounding mountainous terrain.

Velocity patterns are also affected by the sinuosity of a waterway. Within streams with some meandering characteristics, channel velocities are higher along the exterior bends of streams. Stream banks along the exterior bends of meandering streams are subject to erosion due to forces exerted by moving waters while deposition of material often occurs along interior bends due to lower velocities. Therefore, sites along the exterior bends of streams should be considered at risk for higher floodwater velocities. Figure C-8 illustrates a meandering stream system where there are several exterior bends.

Stream hydraulics can be greatly impacted by flow constrictions within the waterway, including bridges, culverts, and levees. Higher floodwater velocities are often observed both within the constricted area and directly downstream of these constrictions. Velocity within an open stream is equal to the discharge rate divided by the flow area. When a constriction reduces the area that water may flow through, water must either flow faster or pond up (thereby reducing the discharge rate); it often does both.

Typically there is some ponding or storage upstream of a constriction during major flooding, but the velocity is also likely to increase dramatically through and just downstream of the

constriction. As the flow area decreases, the depth of the water will also increase through the constriction and continue to be elevated for some time downstream of the constriction as the flow area gradually expands into more natural terrain. Therefore, areas just downstream of constrictions may be prone to high velocity waters during flooding.

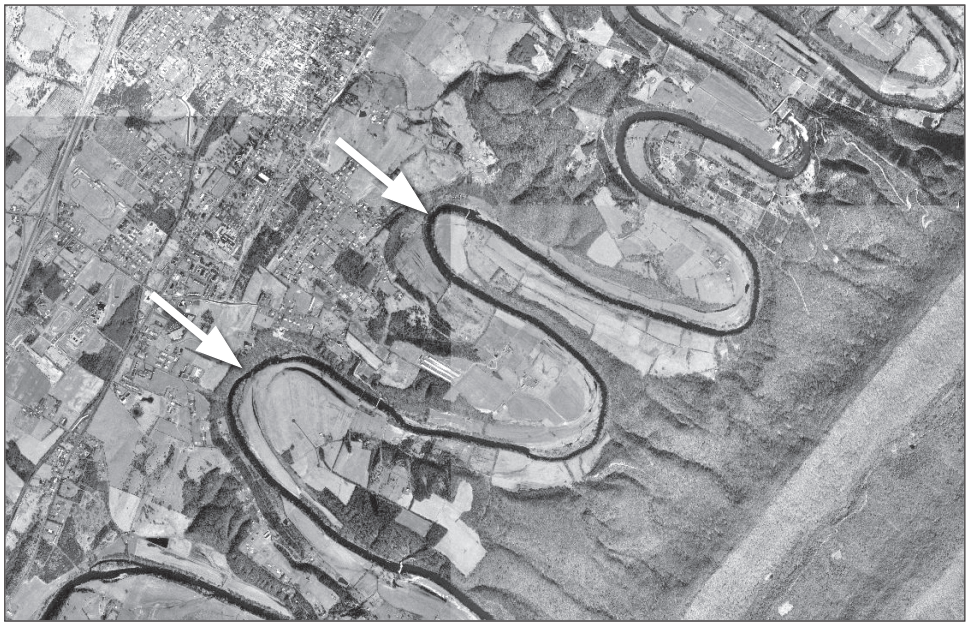


Figure C-8. Meandering stream system. Velocities are generally higher along the outer bends of streams.

D. Definitions

GENERAL NOTE: NFIP definitions in quotes taken from 44 CFR 59.1 unless otherwise noted.

Base flood – Defined by the NFIP as "The flood having a one percent chance of being equaled or exceeded in any given year." The base flood is also called the 100-year flood.

Base flood elevation (BFE) – The elevation of the base flood as given in the community's FIRM and FIS.

Breakaway wall – Defined by the NFIP as "A wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system." Breakaway walls are used in V1-30, VE, and V zones to enclose parking, building access, and storage areas below buildings.

Coastal A Zone – See Limit of Moderate Wave Action (LiMWA).

Coastal High Hazard Area – Defined by the NFIP as "An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources." Coastal High Hazard Areas are identified as V1-30, VE, and V zones on FIRMs.

Community – Defined by the NFIP as "Any State or area or political subdivision thereof, or any Indian tribe or authorized tribal organization, or Alaska Native village or authorized native organization, which has authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction."

Design flood elevation (DFE) – The elevation to which development in the regulatory floodplain is built. The minimum requirement for this elevation in NFIP communities is the BFE. In areas where a higher degree of protection is promoted or required, a freeboard is added; in this case, the DFE is some height (1, 2, or more feet) above the BFE. The 2009 International Residential Code Sections R 322.2.1 and R 322.3.2 require a minimum DFE equal to the BFE plus 1 foot for elevation projects located in Coastal A zones and Coastal High Hazard Areas.

Enclosed areas – The portion of an elevated building below the BFE that is partially or fully surrounded by solid (including breakaway) walls. These enclosed areas can only be used for parking, building access, or storage and must meet other construction requirements.

Encroachment – Any type of development within the floodplain that results in a loss of its flood carrying capacity. Encroachments in floodways are particularly important in floodplain development because, under NFIP minimum requirements, any development within the floodway that results in an increase in the BFE elevation is not permitted.

Existing manufactured home park or subdivision – Defined by the NFIP as "A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by a community."

Expansion to an existing manufactured home park or subdivision – Defined by the NFIP as "The preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads)."

Flood damage-resistant material – Any building material capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than low-cost cosmetic repair.

Flood depth – The difference in height between the water surface elevation at the time of flooding and the normal grade elevation of the flooded area.

Flood Hazard Boundary Map (FHBM) – Defined by the NFIP as "An official map of a community, issued by the Administrator, where the boundaries of the flood and/or mudslide (i.e., mudflow) related to erosion areas having special hazards have been designated as Zones A, M, and/or E."

Flood Insurance Rate Map (FIRM) – Defined by the NFIP as "An official map of a community, on which the Administrator has delineated both the SFHAs and the risk premium zones applicable to the community."

Flood Insurance Study (FIS) – Defined by the NFIP as "An examination, evaluation, and determination of flood hazards and, if appropriate, corresponding water surface elevations, or an examination, evaluation, and determination of mudslide and/or flood-related erosion hazards."

Floodplain – Defined by the NFIP as "Any land area susceptible to being inundated by water from any source."

Floodway – Defined by the NFIP as "The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height."

Freeboard – An additional elevation requirement some height above the BFE; this additional height is added to the BFE to produce the DFE. Freeboard provides a margin of safety above the estimated BFE and against extraordinary or unknown risks. As in all natural hazard events, the design event can only be predicted in probabilistic terms and some uncertainties remain in any analysis. Freeboard is intended to allow for those uncertainties.

Limit of Moderate Wave Action (LiMWA) – The inland limit of the area affected by waves greater than 1.5 feet. The area between this inland limit and the V zone boundary is known as the Coastal A zone.

Manufactured home – Defined by the NFIP as "A structure, transportable in one or more sections, that is built on a permanent chassis and is designed for use with or without a permanent foundation when attached to the required utilities. The term 'manufactured home' does not include a 'recreational vehicle.'"

Manufactured home park or subdivision – Defined by the NFIP as "A parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale."

New manufactured home park or subdivision – Defined by the NFIP as "A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after the effective date of the floodplain management regulations adopted by a community."

Permanent foundation – A foundation constructed of durable materials that may include masonry, reinforced concrete, corrosion resistant steel, or pressure treated timber. Note that this definition of a permanent foundation is provided for the purposes of this publication. The foundation designs provided in Appendix H are considered permanent foundations in accordance with this definition.

Regulatory floodplain – The floodplain to which a community applies their floodplain development regulations. A community participating in the NFIP is required to adopt the floodplain on their FIRM, or use a more restrictive (larger aerial extent or higher floodplain water surface elevations) floodplain.

Special Flood Hazard Area (SFHA) – Defined by the NFIP as "The land in the floodplain within a community subject to a 1-percent or greater chance of flooding in any given year. The area may be designated as Zone A on the FHBM. After detailed ratemaking has been completed in preparation for publication of the FIRM, Zone A is usually refined into Zones A, AO, AH, A1-30, AE, A99, AR, AR/A1-30, AR/AE, AR/AO, AR/AH, AR/A, VO or V1-30, VE, or V." The SFHA is also called the base floodplain, 100-year floodplain, or 1-percent annual chance floodplain.

Structural fill – Engineered fill, compacted to 90 percent compaction, Modified Proctor Test, ASTM D1557. It should have a minimum bearing capacity as recommended by geotechnical engineer, and be free of organic material such as weeds, or grasses, or other organic matter.

Substantial damage – Defined by the NFIP as "Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred."

Substantial improvement – Defined by the NFIP as "Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the 'start of construction' of the improvement. This term includes structures that have incurred 'substantial damage,' regardless of the actual repair work performed. The term does not, however, include either: (1) any project for improvement of a structure to correct existing violations of State or local health, sanitary, or safety code specifications that have been identified by the local code enforcement official and that are the minimum necessary to ensure safe living conditions, or (2) any alteration of a 'historic structure,' provided that the alteration will not preclude the structure's continued designation as a 'historic structure.'"

E. Acronyms and Abbreviations

A

ABS	acrylonitrile butadiene styrene
ACI	American Concrete Institute
ACQ	alkaline copper quaternary
ACZA	ammoniacal copper zinc arsenate
AdCIRC	Advanced Circulation Model
AF&PA	American Forest and Paper Association
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
APA	American Plywood Association
ASCE	American Society of Civil Engineers
ASD	allowable stress design
ASFPM	Association of State Floodplain Managers
ASTM	American Society for Testing Materials
AWC	American Wood Council
AWPA	American Wood Preservers Association

B

BFE	base flood elevation
BMP	braced masonry pier
BPAT	Building Performance Assessment Team

C

C&C	components and cladding
CCA	chromated copper arsenate

CFR	Code of Federal Regulations
CMU	concrete masonry unit
COSAA	Council of State Administrative Agencies
CRS	Community Rating System

D

DAPIA	Design Approval Primary Inspection Agency
DFE	design flood elevation
DFIRM	Digital Flood Insurance Rate Map
DHS	Department of Homeland Security
DMA 2000	Disaster Mitigation Act of 2000

E

ERBS	earthquake-resistant bracing system

F

FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FHWA	Federal Highway Administration
FIA	Federal Insurance Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMHA	Florida Manufactured Housing Association
fps	feet per second
ft	foot or feet
FY	fiscal year

G

g	acceleration due to gravity
GA	ground anchor

GAATP Ground Anchor Assembly Test Protocol

GASP ground anchor with stabilizer plate

GIS Geographic Information System

GPO Government Printing Office

H

H&H hydrologic and hydraulic

HAZUS-MH Hazards U.S. – Multi-Hazard

HEC Hydrologic Engineering Center (USACE)

HEC-HMS Hydrologic Engineering Center's Hydrologic Modeling System

HEC-RAS Hydrologic Engineering Center's River Analysis System

HMS Hydrologic Modeling System

HUD U.S. Department of Housing and Urban Development

HVAC heating, ventilation, and air conditioning

I

IBC International Building Code

ICBO International Council of Building Officials

ICC International Code Council

ID identification

in inch or inches

IRC International Residential Code

ITW Illinois Tool Works

L

lb pound or pounds

LiMWA Limit of Moderate Wave Action

LOMA Letter of Map Amendment

LOMR Letter of Map Revision

M

MAT	Mitigation Assessment Team
MH	manufactured housing
MHCC	Manufactured Housing Consensus Committee
MHCSS	Manufactured Home Construction and Safety Standards
MHI	Manufactured Housing Institute
MHIA 2000	Manufactured Housing Act of 2000
MHRA	Manufactured Housing Research Alliance (now Systems Building Research Alliance)
mm	millimeter
mph	miles per hour
MWFRS	main wind force resisting system

N

NAHB	National Association of Home Builders
NAVD	North American Vertical Datum
NCSBCS	National Conference of States on Building Codes and Standards
NDS	National Design Standard
NEHRP	National Earthquake Hazards Reduction Program
NFHL	National Flood Hazard Layer
NFIA	National Flood Insurance Act
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NGVD	National Geodetic Vertical Datum
NIST	National Institute of Standards and Technology
NRCS	National Resources Conservation Service
NWIS	National Water Information System

O

o.c.	on center
OC	Oversight Committee

P

PATH	Partnership for Advancing Technology in Housing
pcf	pounds per cubic foot
PFGMH	Permanent Foundations Guide for Manufactured Housing
plf	pounds per linear foot
psf	pounds per square foot
psi	pounds per square inch

R

RiskMAP	Risk Mapping, Assessment, and Planning
RM	reinforced masonry
RUNUP	wave runup module

S

SBRA	Systems Building Research Alliance (formerly Manufactured Housing Research Alliance)
SD	substantial damage
SEI	Structural Engineering Institute
SFHA	Special Flood Hazard Area
SI	substantial improvement
STP	Standard Torque Probe

T

TVA	Tennessee Valley Authority

U

USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USDA	United States Department of Agriculture
USGS	United States Geological Survey

W

WF	wood framed
WHAFIS	Wave Height Analysis for Flood Insurance Studies
WSPRO	water surface profile computation module

F. Example Calculations

Design a CMU pier and ground anchor foundation for a manufactured home to be placed in an SFHA Zone AE having a flood velocity of 2 fps. The BFE is 9 feet and existing ground elevation is approximately 7 feet. The flood depth is 2 feet and the freeboard is 1 foot, which yields a DFE depth of 3 feet. The manufactured home dimensions for these example calculations are shown in Figure F-1. The manufactured home is a single unit, 16 feet wide and 60 feet long with a 30-degree gable roof with a 1-foot overhang. Roofing members are spaced 16 inches on center (o.c.). The manufactured home weighs 20 psf. Assume an NFPA 5000 soil classification of soft, sandy clay, or clay (allowable bearing pressure q_a =1,000 psf ; ultimate bearing pressure q_u = 2,000 psf). Use ASCE 7 to calculate loads.

Foundation loads selected for this example of a manufactured home in an SFHA differ from those that may be found in HUD standard 24 CFR 3280. Design loads in this example are in accordance with ASCE 7-05 and other standards.

These example calculations assume transverse wind loads produce the controlling loading. Wind in the direction parallel to the roof ridge may produce greater loads for certain cases and must be evaluated during final design.

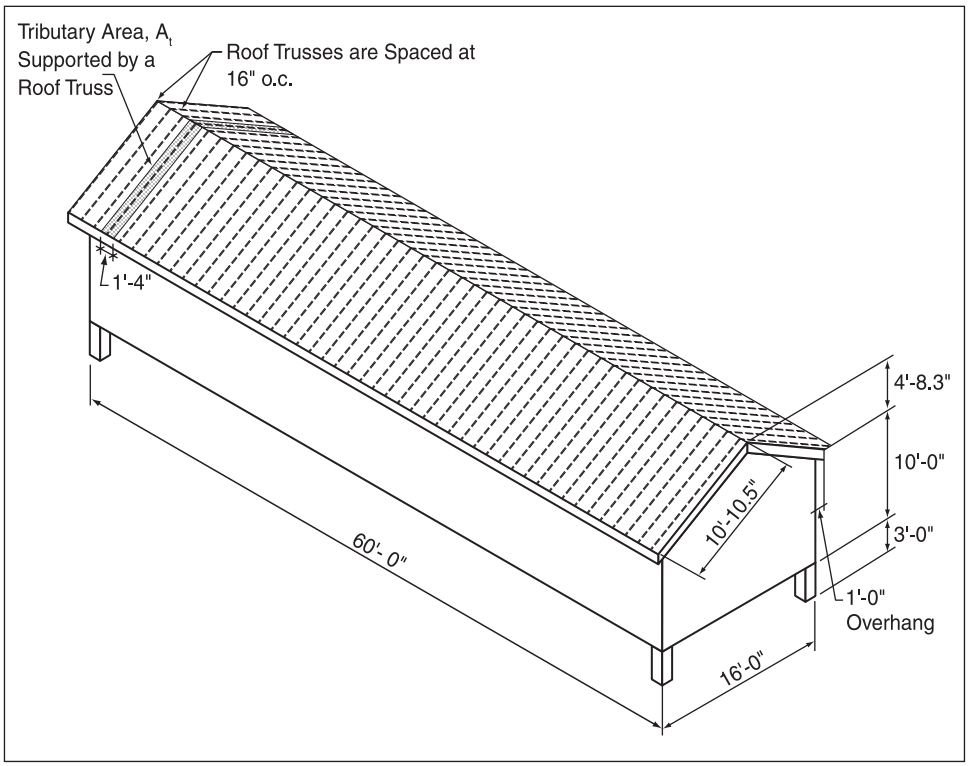


Figure F-1. Manufactured home dimensions.

ASCE 7-05

Step 1: Determine Design Criteria

NORMAL LOADS

ASCE 7-05
Table 4-1

Dead Load (D)

D = 20 psf Given in the example statement

Live Load (L)

L is based on one- and two-family dwellings

L = 40 psf

Roof Live Load (L_r)

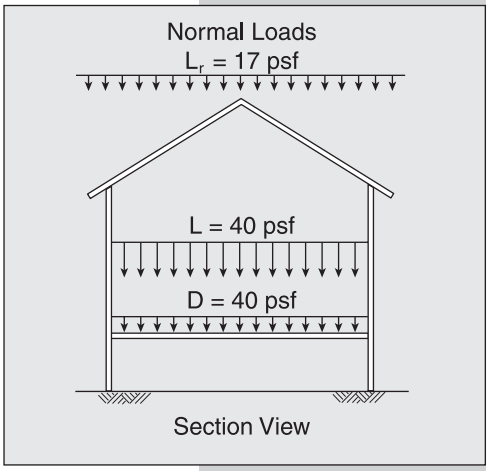
$L_r = 20R_1R_2 = 20(1)(0.85) = 17$ psf

$R_1 = 1$ for $A_t \leq 200$ ft^2

$A_t = 2(9.2\ ft)(16\ in)\left(\frac{1\ ft}{12\ in}\right) = 24.5\ ft^2$

F = number of inches of rise per foot

$F = 1ft\left(\frac{12\ in}{1\ ft}\right)\tan 30^\circ = 7\ in$



Note that the roof live load falls between the limits given:

$12 \leq L_r \leq 20$

ENVIRONMENTAL LOADS

ASCE 7-05

Wind Loading

Section 6.2

Structure is a regular shape, located in a windborne debris region with terrain classification of Exposure C and surrounded by flat terrain.

Mean roof height (h)

h = 3 ft + 10 ft + 0.5(4 ft)

= 15 ft

h < 16 ft (least horizontal dimension)

Calculations are for a foundation system, which is a main wind force resisting system (MWFRS).

Velocity Pressures

Section 6.5

Velocity pressures are determined using

Method 2: Analytical Procedure

(A simplified alternative is to use ASCE 7, Section 6.4, Method 1. Wind pressures are tabulated for basic conditions. The wind pressure must be adjusted for mean roof height and exposure category.)

Velocity Pressure Coefficient (q_z)

Section 6.5.10
Eq. 6-15
Section 6.5.6
Table 6-3

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I$$

Velocity pressure exposure coefficient evaluated at height *z* (the height above ground level in feet) (K_z)

Section 6.5.6

$K_z = 0.85$

Topographical factor (K_{zt})

Section 6.5.4.4
Section 6.5.5
Table 6-1
Section 6.5.4

$K_{zt} = 1$ (assume a flat surface)

Wind directionality factor (K_d)

$K_d = 0.85$

Basic Wind Speed (V)

Section 6.5.11.1
Figure 6-5

$V = 110$ mph (3-second gust)

$I = 1$ (Category II building: Table 1-1 (ASCE 7))

Section 6.5.11.2.1
Figure 6-6

Therefore, $q_z = 0.00256(0.85)(1)(0.85)(110)^2(1)$

$= 23$ psf

Design Pressures for MWFRS

Internal Pressure Coefficient (GC_{pi})

$GC_{pi} = \pm 0.18$

External Pressure Coefficient (C_p)

h = Mean roof height, in feet

L = Horizontal dimension of building, in feet, measured parallel to wind direction

B = Horizontal dimension of building, in feet, measured normal to wind direction

Figure 6-6

Table F-1 shows the External Pressure Coefficients calculated for the windward, leeward and side walls. Computations of the External Pressure Coefficients for the windward and leeward roof are shown Table F-2.

Table F-1. External Wall Pressure Coefficients

Surface	Wind Direction	L/B	C_p
Windward Wall	n/a	n/a	0.8
Leeward Wall	Perpendicular to roof ridge	$\frac{16\,ft}{60\,ft} = 0.27$	-0.5
Side Wall	n/a	n/a	-0.7

Figure 6-6

Table F-2. External Roof Pressure Coefficients

Surface	Wind Direction	h/L	C_p
Windward Roof	Perpendicular to roof ridge	$\frac{15\,ft}{16\,ft} = 0.94$	-0.3 0.2
Leeward Roof			-0.6

Figure 6-6
Section 6.5.8
Eq. 6-17

Foundation systems are considered rigid, therefore, G = 0.85.

Design Pressure (p)

The basic pressure equation (ASCE 7 6-17), which includes the internal pressure coefficient is as follows:

$$p = qGC_p - q_i(GC_{pi})$$

However, this would only be used if designing individual components whose effective tributary area is equal to or greater than 700 sf (ASCE 7-05 6.5.12.1.3 and IBC 2006 1607.11.2.1). When determining loads on the global structure (i.e., shear walls or foundation design), the internal pressure components will act in equal and opposite directions on the roof/floor and the leeward/windward walls, thereby algebraically canceling each other. The resulting simplified form of the pressure equation is:

$$p = q \times GC_p$$

Table F-3 summarizes the design pressures calculated using this simplified wind design pressure equation. Figure F-2 shows the application of these design pressures on the structure. For foundation design, internal pressures need not be considered since internal pressure on windward walls, leeward walls, floors, and roofs cancel each other. For example, internal pressures acting on a windward wall are equal and opposite to those acting on a leeward wall and the net force on the foundation from internal pressures is zero.

While internal pressures cancel, internal pressures for a partially enclosed building have been included in the example. This is to provide an example of more general wind load calculations.

Table F-3. Design Pressures for Wind Perpendicular to the Roof Ridge

Surface	Design Wind Pressure Calculations	pressure (psf)
Windward Wall	p = 23 psf(0.85)(0.8)	15.7
Leeward Wall	p = 23 psf(0.85)(-0.5)	-9.8
Side Walls	p = 23 psf(0.85)(-0.7)	-13.7
Windward Roof	p = 23 psf(0.85)(-0.3)	-5.9
	p = 23 psf(0.85)(0.2)	4.0
Leeward Roof	p = 23 psf(0.85)(-0.6)	-11.8

MWFRS Roof Overhang Pressures

ASCE 7-05

ASCE 7 only addresses the windward overhang, specifying the use of a positive pressure coefficient of $C_p = 0.8$. Acting on the bottom surface of the overhang in combination with pressures acting on the top surface. For the leeward overhang, the coefficient for the leeward wall ($C_p = -0.5$) could be used, but the coefficient has been conservatively taken as zero.

$$p = 23 \text{ psf}(0.85)(0.8)$$

$$= 15.7 \text{ psf}$$

Section 6.5.11.4.1

$$p_{OH} = -5.9 \text{ psf} - 15.7 \text{ psf} = -21.6 \text{ psf}$$

A conservative simplification is to use the wind pressure acting away from the roof case for uplift roof pressure simultaneously with the wind pressure toward the roof for the lateral roof pressure.

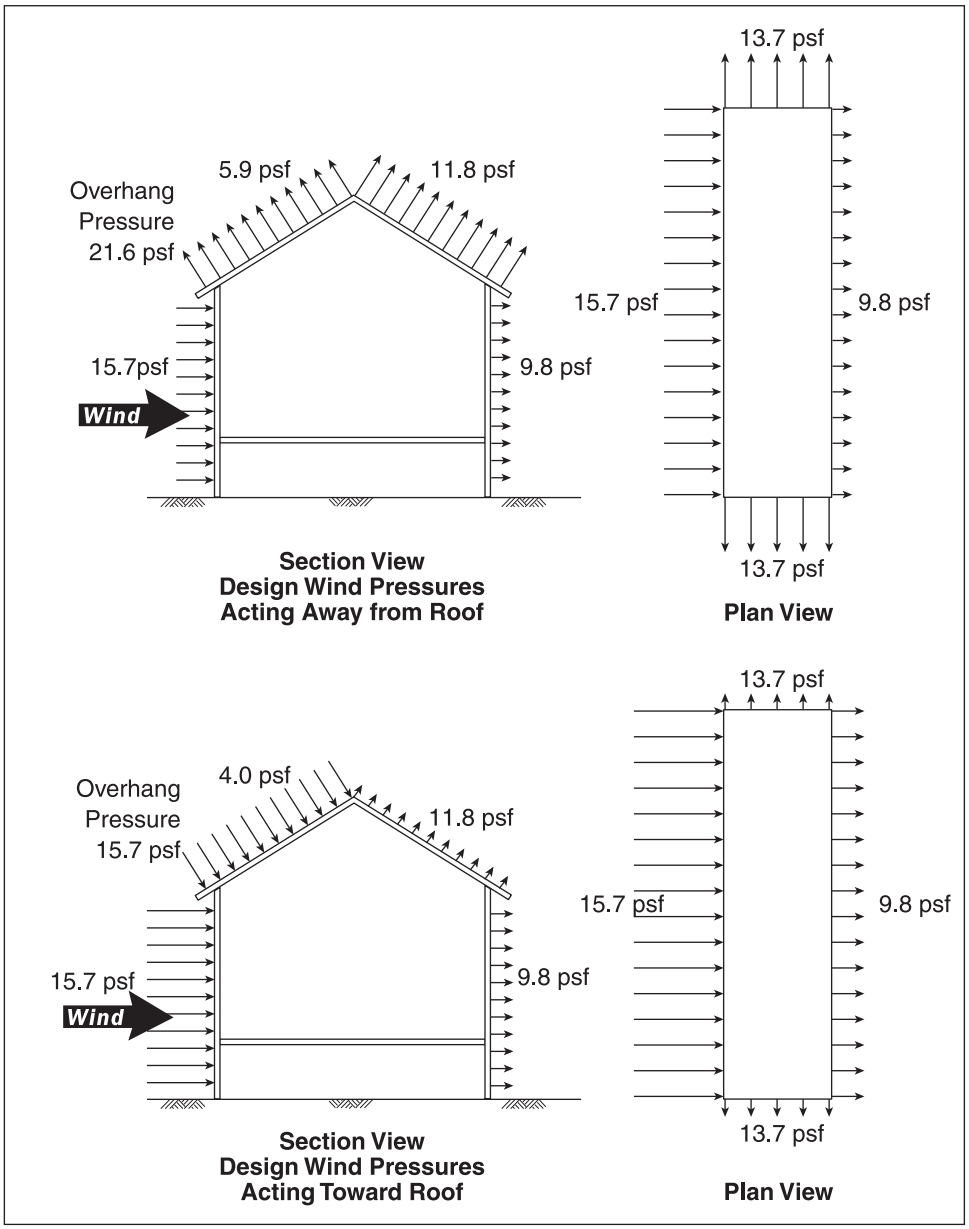


Figure F-2. Maximum uplift and lateral wind loads on roof.

SNOW LOADING

Ground Snow Load (p_g)

$p_g = 20$ psf

Flat Roof Snow Load (p_f)

$p_f = 0.7 C_e C_t I p_g$

$p_f = 0.7(1.0)(1.0)(1.0)(20)$

$= 14$ psf

But not less than $p_f = (I) p_g = 20$ psf

ASCE 7-05

Section 7.2
Figure 7-1

Section 7.3
Eq. 7-1

Exposure Coefficient (C_e) — Section 7.3.1, Table 7-2

C_e = 1.0 (partially exposed roof)

Thermal Factor (C_t) — Section 7.3.2, Table 7-3

C_t = 1.0

Importance Factor (I) — Section 7.3.3, Table 7-4

I = 1.0 (Category II building: Table 7-4 (ASCE 7))

Sloped Roof Snow Load (p_s) — Section 7.4

$p_s = C_s p_f$ — Eq. 7-2

$= (1.0)(20 \text{ psf})$

$= 20 \text{ psf}$

Warm Roof Slope Factor (C_s) — Section 7.4.1, Figure 7-2

C_s = 1.0 (asphalt shingle not slippery)

Unbalanced Roof Snow Load (p_u) — Section 7.6

Since the roof's eave to ridge distance ≤ 20 ft, unbalanced uniform snow loads shall be applied as follows:

$P_{windward} = 0.3\ p_s$ — Section 7.6.1

$= 6 \text{ psf}$

$P_{leeward.1} = p_s$

$= 20 \text{ psf}$

$P_{leeward.2} = (h_d)(\gamma)/\sqrt{(S)}$

$= (1.44 \text{ ft})(16.6 \text{ pcf})/\sqrt{(1.73)}$

$= 18.2 \text{ psf}$

From the ridge toward the leeward eave a distance of: — Figure 7-9, Eq. 7-3

$x = (8/3)(h_d)\sqrt{(S)}$

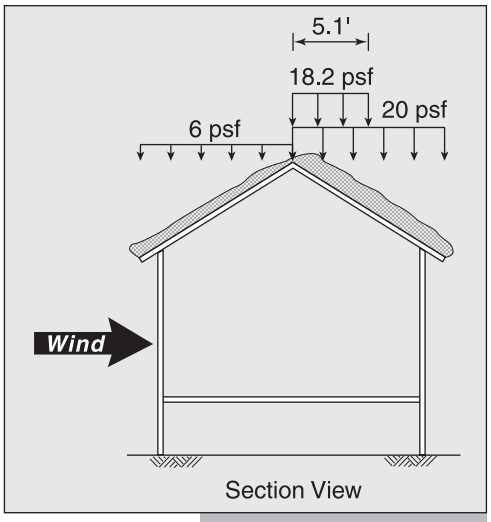
$= 5.1 \text{ ft}$

$h_d = 1.44 \text{ ft}$

$\gamma = 0.13\ p_g + 14 \leq 30 \text{ pcf}$

$= 16.6 \text{ pcf}$

FLOOD LOADING



Hydrostatic Load (F_h)

If the manufactured home is elevated above the BFE on an enclosed foundation, venting must be provided in all manufactured homes placed in a SFHA; the hydrostatic forces on either side of the foundation wall will cancel. However, the hydrostatic load is calculated because it is used in the hydrodynamic load calculation.

$$F_h = \tfrac{1}{2} P_h H$$

Hydrostatic Pressure (P_h)

$$P_h = \gamma H$$

Specific Weight of Fresh Water (ω)

$$\gamma = 62.4\ pcf$$

Floodproofing Design Depth (H)

H = 2 ft (base flood depth) + 1 ft

Note: A 1-foot freeboard is added to the BFE depth to provide a protection above the BFE; 3 feet becomes the "design" depth or the DFE.

Hydrodynamic Load

ASCE 7

The hydrodynamic load is calculated by converting it to an equivalent hydrostatic load by increasing the flood depth. The increase in flood depth is referred to as d_h.

$$d_h = \frac{C_d V^2}{2g} = \frac{2.0(2\ ft/s)^2}{2(32.2\ ft/s)} = 0.13\ ft$$

Eq. 7-5

Drag Coefficient (C_d)

In the above equation, a value of 2.0 was assumed for C_d. This is a conservative estimate; the actual value for C_d could be anywhere between 1.2 and 2.0.

FEMA's *Coastal Construction Manual* (FEMA 55) recommends a value of 2.0 for square or rectangular piles and 1.2 for round piles.

For additional guidance regarding a0^d `lbc^a`fbkqp) obcbo ql Slir j b FF of the U.S. Army Corps of Engineers' *Shore Protection Manual* (USACE 1984), FEMA 55, and the *Engineering Principles and Practices for Retro-^aqqfkd Cil la*Mo lkb Obpfabkqf^i Pqo r`* tures* (FEMA 259).

Acceleration Due to Gravity (g)

$g = 32.2\ ft/s^2$

with a hydrodynamic pressure of

$$P_{hydr} = \gamma(d_h) = 62.4\ pcf\ (0.13\ ft) = 8.2\ psf$$

The equivalent hydrostatic load ($F_{h/ad}$) taken into consideration the hydrodynamic load is :

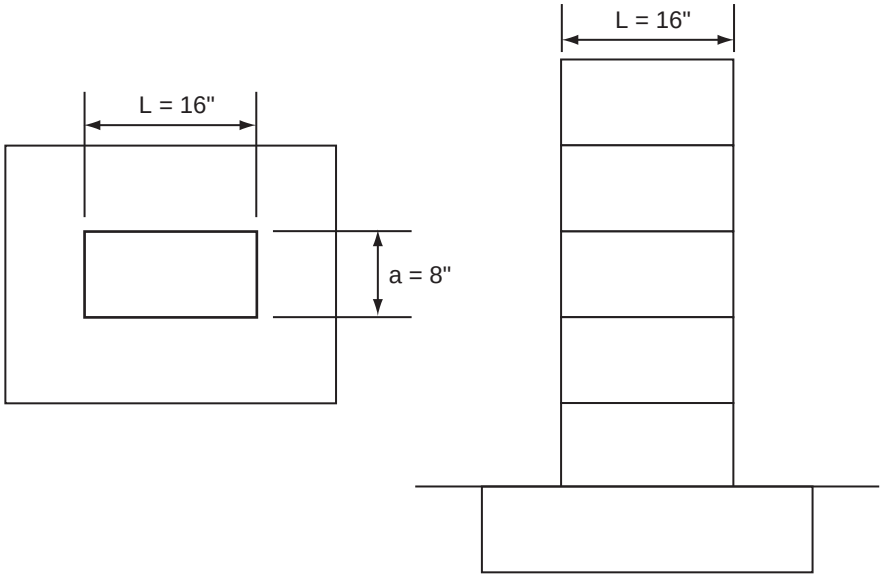
$$F_{h/ad} = P_{hydr} \times H = 8.2\ psf \times 3\ ft = 24.6\ plf$$

Since piers are 16 inches wide, the total hydrodynamic force on the pier is

$$= 24.6 \frac{lb}{ft} \; 16\ in \; \frac{1\ ft}{12\ in} \; 32\ lbs \text{ per pier}$$

CHECK SCOUR

Reference: Publication No. FHWA NHI 00-001, *Evaluating Scour at Bridges,* 4th Edition, May 2001, Hydraulic Engineering Circular No. 18.



$$\frac{Y_s}{Y_1} = 2.0 \times (K_1) \times (K_2) \times (K_3) \times (K_4) \times (a/Y_1)^{0.65} \times F_{r1}^{0.43}$$

Where: Y = Scour depth

Y_1 = Flow depth directly upstream of pier

a = Pier width (ft.)

L = Pier length (ft)

F_{r1} = Froude number

$F_{r1} = V_1/(gY_1)^{1/2}$

Where V_1 = Mean velocity of flow directly upstream of pier

g = acceleration due to gravity (32.2 feet/sec^2)

K_1 = Factor for pier nose shape. For square nose

K_2 = Factor for Angle of attack . $K_2 = (\text{cosine } \varphi + (L/a) \text{ x sine } \varphi)^{0.65}$

K_3 = Factor for bed condition/. $K_3 = 1.1$

K_4 = Factor for armoring by bed material size.

Project parameters:

Flood low = 2 fps

Flood depth = 3 ft

Assume flood angle of attack = 0º

So that:

$K_1 = 1.1$ (Table 6.1)

$K_2 = [\text{cosine } 0^o + (L/a) \text{x sine } 0^0]^{0.65} = [1.00 + (1.33'/0.67") \text{ x } 0]^{0.65} = 1.00$

K_3 = Factor for bed condition/. $K_3 = 1.1$ (Table 6.3)

K_4 = Factor for armoring by bed material size. $K_4 = 1.0$ unarmored

$F_{r1} = V_1/(gY_1)^{1/2} = 2/[32.2 \text{ x } 3]^{1/2} = 2/9.84 = 0.203$

And

$$\frac{Y_s}{Y_1} = (2) \text{ x } (1.1) \text{ x } (1.0) \text{ x } (1.1) \text{ x } (1.0) \text{ x } (0.67/2)^{0.65} \text{ x } (0.203)^{0.43}$$

$$\frac{Y_s}{Y_1} = (2.42) \text{ x } (0.491) \text{ x } (.504) = 0.6$$

$Y_s = (0.6) \text{ x } (Y_1) = (0.6)\text{x}(3) = 1.8$ ft

Scour protection or increased footing embedment required.

Step 2: Select a Design Methodology and Assess Load Combinations and Failure Modes

Figure F-3 illustrates the loads applied to the manufactured home. Table F-4 lists the nomenclature of the applied loads shown in Figure F-3.

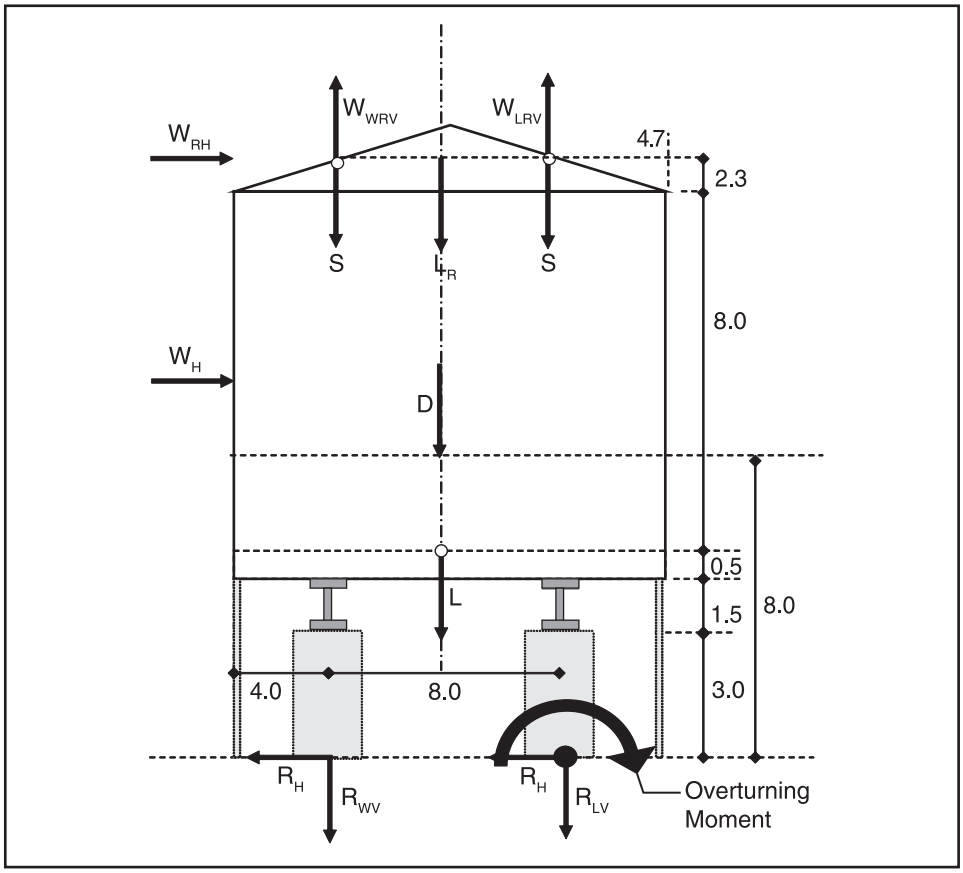


Figure F-3. Loading on a manufactured home.

Table F-4. Load Nomenclature

Nomenclature	Load Description
D	dead load
L	live load
L_R	roof live load
R_H	horizontal reaction
R_{LV}	leeward vertical reaction
R_{WV}	windward vertical reaction
S_B	balanced snow load
W_H	horizontal wall wind pressure
W_{RH}	roof horizontal wind pressure

Table F-4. Load Nomenclature (continued)

Nomenclature	Load Description
W_{LRV}	leeward roof vertical wind pressure
W_{WRV}	windward roof vertical wind pressure

Note that snow load governs over roof live load and wind downward load, and wind lateral load governs over earthquake lateral load. Load combinations for non-governing cases are not shown.

For the purposes of these calculations, the worst case wind load is taken to be perpendicular to the roof ridge for all failure modes. Wind in the direction parallel to the roof ridge may produce greater loads for certain failure modes.

Uplift and Downward Failure Mode

Uplift failure is a vertical force phenomenon. The loads that act vertically are wind, snow, dead, and live loads. Table F-5 summarizes the loads that influence uplift and downward failure mode. Table F-6 assesses uplift and downward failure load combinations. Note that uplift is based on MWFRS pressures for the global foundation design. Design of the connections to the foundation may require components and cladding (C&C) pressures to be used.

Table F-5. Vertical Load Values

Load Type	Total load acting on the structure and, therefore, must be supported by the foundation
D	D = [dead load per square foot][width of the manufactured home] D = [20 psf][16 ft] D = 320 lbs per linear ft of manufactured home length
L	L = [live load per square foot][width of the manufactured home] L = [40 psf][16 ft] L = 640 lbs per linear ft of manufactured home length
L_r	L_r = [roof live load per square foot][width of the manufactured home] L_r = [17 psf][18 ft] L_r = 306 lbs per linear ft of manufactured home length

Table F-5. Vertical Load Values (continued)

Load Type	Total load acting on the structure and, therefore, must be supported by the foundation
W	Maximum wind uplift loads occur for winds parallel to the roof ridge at the windward end. $W = W_{WRV} + W_{LRV}$ = [(vertical component roof wind pressures)(area roof)]/manufactured home length W = [-17.6 psf][(9 ft)(15 ft)(2)] 0 ft to 15 ft + [-9.8 psf][(9 ft)(15 ft)(2)] 15 ft to 30 ft + [-5.9 psf][(9 ft)(30 ft)(2)] 30 ft to 60 ft W = -10,584 lbs/60 ft = -176 lbs per linear foot of manufactured home length (average) Fk qefp `^pb) sboqf`^i rmifcq il^ap ^ob il t ^ka pl qefp pf j mifª`^qflk fp ^``bmq^_ib+ El t bsbo) ql account for the unbalanced uplift if wind loads were higher, either overturning in this direction would need to be considered, or the windward uplifts conservatively made symmetrical about the middle. Maximum wind downward loads occur for wind perpendicular to the roof ridge; however, they are much less than, and do not govern over, roof live or snow loads.
S	S = [snow pressure][horizontal projected roof area] S = [20 psf][(9 ft)]SW + [20 psf][(9 ft)]SL S = 360 lbs per linear ft of manufactured home length

Table F-6. Vertical Failure Mode ASD Load Combinations

	Load Combinations
4	D + 0.75L + 0.75S 320 lbs + 0.75(640 lbs) + 0.75(360 lbs) = 1,070 lbs per linear ft of manufactured home length
7	0.6D + W 0.6(320 lbs) - 176 lbs = 16 lbs per linear ft of manufactured home length acting downward

Note that, for load combination 7, the 0.6 load factor should be applied to the dead load that would actually be present over the whole structure. Additions to the dead load tabulation such as mechanical and miscellaneous or shingles should not be included in this value as they may not be present in all areas or during a high-wind event and their inclusion would not be conservative.

Sliding or Shearing Failure Mode

Sliding failure is a lateral force phenomenon. The loads that act laterally are wind and flood loads. Table F-7 summarizes the lateral loads and their values. Maximum lateral wind loads occur when the wind is perpendicular to the roof ridge. Note that lateral wind loads act on the overall structure (i.e., foundation), whereas flood loads act on the individual piers. Table F-8 gives the load combinations for sliding failure. Once the number of piers is defined, the hydrodynamic forces on these piers are to be added to load combination 4, and the foundation design will have to be checked to make sure it can resist the added hydrodynamic loads.

Table F-7. Lateral Load Values

Load Type	Total load acting on the structure and, therefore, must be supported by the foundation
W	Maximum lateral wind loads occur for winds ⊥ to the roof ridge $W = W_{RH} + W_H =$ [lateral roof pressures][roof height] + [wall pressures][wall height] W = [4 psf – (-11.8 psf)] (4.7 ft) [(15.7 psf + 9.8 psf)(10 ft)] W = 329.3 lbs per linear ft of manufactured home length
F_a	Hydrodynamic load per pier F_a = [hydrodynamic force][pier length] F_a = 32.8 lbs per pier Assume total of 9 piers x 2 rows for 1st iteration F_a = (32.8 lbs per pier)(9 piers per row)(2 rows) F_a = 590.4 lbs / 60 ft = 9.84 lbs per linear ft of manufactured home length

Table F-8. Sliding Load Combinations

	Load Combinations
5	$W + 1.5F_a$ 329.3 lbs + 1.5(9.84 lbs) = 344 lbs per linear ft of manufactured home length

Note: The vertical gravity loads are not considered to be conservative. Thus, the frictional resistance of the footings under the piers has been neglected. This component may be used in borderline situations at the discretion of the engineer.

Overturning Failure Mode

Overturning failure results from loads that act on the whole structure and pivot about the bottom of the leeward pier. Dead, live, wind, and snow loads can all influence the overturning moment. Table F-9 summarizes the moments that affect overturning due to wind in this case. Table F-10 assesses the moment load combinations. Only the portions of the roof and floor live loads that are over the part that cantilevers out past the leeward pier will contribute to the overturning. Since this is the worst overturning case for each, only these conditions will be calculated.

Table F-9. Moment Load Values

Moment Type	Total moment about the bottom of the leeward foundation support (positive moment is counter clockwise)
D	D = [dead load per square foot][home width][moment arm] D = [20 psf][(16 ft)(4 ft)] D = +1,280 ft-lbs per linear ft of manufactured home length
L	L_1 = [live load per square foot][home width][moment arm] L_1 = [40 psf][(16 ft)(4 ft)] L_1 = 2,560 ft-lbs per linear ft of manufactured home length L_2 = [live load per square foot][cantilever width][moment arm] L_2 = [40psf][4 ft][-1 ft] L_2 = -160 ft lbs per linear ft of manufactured home length
L_r	L_r = [roof live load per square foot][roof width][moment arm] L_r = [17 psf][4 ft][1 ft] L_r = -68 ft-lbs per linear ft of manufactured home length
W	**WIND PERPENDICULAR TO THE ROOF RIDGE** W_{WRV} = [vertical component roof wind pressures][roof width][moment arm] W_{WRV} (-21.6 psf)(1 ft)(12.5 ft) + (-5.9 psf)(8 ft)(8 ft) W_{WRV} = -648 ft-lbs per linear ft of manufactured home length W_{LRV} = [vertical component roof wind pressures][roof width][moment arm] W_{LRV} (-11.8 psf)(9 ft)(-0.5 ft) W_{LRV} = +53 ft-lbs per linear ft of manufactured home length W_{RH} = [horizontal component roof wind pressures][roof height][moment arm] W_{RH} = [4 psf – (-11.8 psf)](-4.67 ft)](15.3 ft) W_{RH} = -1,129 ft-lbs per linear ft of manufactured home length W_{W+L} = [windward wall pressure + leeward wall pressure][home's height from ground to roof eave][moment arm] W_{W+L} = [15.7 psf + 9.8 psf](10 ft)(-8 ft) W_{W+L} = -2,040 ft-lbs per linear ft of manufactured home length
F_a	Hydrodynamic load on piers F_a = [horizontal component][moment arm] = (9.84 plf)(-3 ft/2) = -15 ft-lbs per linear foot of manufactured home length
S	S_B = [balanced snow pressure][horizontal projected roof area][moment arm] S_B = [20 psf][18 ft][-4 ft] S_B = 1,440 ft-lbs per linear ft of manufactured home length

Table F-10. Overturning Load Combinations

Moment Load Combinations (positive moment is counter clockwise)	
6	D + 0.75W + 0.75L + 0.75L_r + 1.5F_a (Partial live loading to produce max OT) (1,280 ft-lbs) + (0.75)(-648 ft-lbs + 53 ft-lbs – 1,129 ft-lbs – 2,040 ft-lbs) + (0.75)(-160 ft-lbs)+ (0.75) (-68 ft-lbs) + (1.5)(-15 ft-lbs) = -1,737 ft-lbs per linear ft of manufactured home length D + 0.75W + 0.75L + 0.75S + 1.5F_a (Full live and snow to produce max downward reaction) (1,280 ft-lbs) + (0.75)(-648 ft-lbs + 53 ft-lbs – 1,129 ft-lbs – 2,040 ft-lbs) + (0.75)(-2,560 ft-lbs) + (0.75)(1,440 ft-lbs) + (1.5)(-15 ft-lbs) = 1,435 ft-lbs per linear ft of manufactured home length
7	0.6D + W + 1.5F_a (0.6)(1,280 ft-lbs) + (-648 ft-lbs + 53 ft-lbs – 1,129 ft-lbs – 2,040 ft-lbs) + (1.5)(-15 ft-lbs) = -3,019 ft-lbs per linear ft of manufactured home length

Table F-11 summarizes the load combinations that govern for each of the three failure modes. The maximum roof vertical and lateral load cases are assumed to act simultaneously as a conservative simplification.

Table F-11. ASD Load Combinations for Example Problem (loads are in pounds per linear foot)

Failure Modes	Load Combinations		
	4	5	7
Uplift	1,070 lbs	n/a[1]	15 lbs
Sliding	n/a[1]	313 lbs	n/a[1]
Overturning	n/a[1]	n/a[1]	-979 ft-lbs

[1] Load combination does not govern.

Load combinations 1-3 do not govern. Load combination 6 does not comply with HUD 24 CFR 3280.

Step 3: Select Foundation Type and Materials

The example statement specified a CMU pier and ground anchor foundation type. Since the flood velocity is 2 fps, CMU piers must have surface bonded mortar that meets ASTM C887-79a (2001) and ASTM C946-91 (2001) and maintain bonding between CMUs.

Step 4: Determine Forces at Connections and on Foundation Components

CMU piers transfer the compressive loads from the manufactured home into footings and then into the ground. The masonry piers are not considered to provide any lateral or uplift

resistance. The governing load combination for downward forces is the vertical failure mode (load combination 4), which produces a total downward force from the manufactured home equal to

(downward force) (length of manufactured home)

Therefore, (1,070 lbs) (60 ft) = 64,200 lbs

This downward force governs the number of footings and, therefore, piers needed to transfer the downward load into the ground.

Following the braced masonry pre-engineered foundation design for flood velocities over 2 fps specification given in Chapter 10 of the use of a dry-stack 16-inch by 8-inch block pier with a minimum of an 1/4-inch thick surface bonded mortar and a 24-inch square, 10-inch deep footing, calculate the number of footings needed to adequately transfer the downward loads to the ground.

$$\text{Required footing area} = \frac{\textit{comprehensive load}}{\textit{allowable soil bearing capacity}}$$

Consult the geotechnical engineer for the ultimate soil bearing capacity value. An approximate method to calculate the ultimate soil bearing capacity is to multiply the allowable soil bearing capacity by a safety factor. The maximum pressure given in the NFPA 5000 Soil Classification Table can also be used as the ultimate soil bearing capacity.

$$\text{Required footing area} = \frac{64{,}200 \text{ lbs}}{1{,}000 \text{ psf}} = 64 \text{ ft}^2$$

$$\text{Individual footing area} = (24 \text{ in} \times 24 \text{ in}) \left(\frac{1 \text{ ft}^2}{144 \text{ in}^2} \right) = 4 \text{ ft}^2$$

$$\text{Number of footings} = \frac{\textit{total required footing area}}{\textit{individual footing area}}$$

$$= \frac{64 \text{ ft}^2}{4 \text{ ft}^2} = 16 \text{ footings/piers}$$

Therefore, provide 8 piers per side of the manufactured home

$$\text{Pier spacing} = \frac{\textit{manufactured home length}}{\textit{(number piers per side-1)}}$$

$$= \frac{60 \text{ ft}}{8\text{-}1} = 8.6 \text{ ft}$$

The maximum spacing of the piers is set to 8 feet to provide effective floodborne debris protection. To protect against floodborne debris, it is assumed that 1 pier will be lost due to floodborne debris.

Minimum number of piers = $\frac{60 \text{ ft}^2}{8 \text{ ft}} + 1 = 8.5$ piers, say 9 piers per side (i.e., 8 spaces at 7.5 feet). Therefore, the home will be supported by a total of 18 piers (9 piers on each side) spaced at 7.5 feet.

Lateral wind loads are resisted by the strapping and ground anchors. The final number of piers equals the initial guess; therefore, the lateral load on the piers does not have to be updated.

Calculate the number of anchors needed to resist sliding failure.

The recommended design stiffness of the anchors in Table 7-5 in this guide is given for 5-foot anchors installed at 45 degrees and axially loaded is 1,200 lb/in (Figure 7-4). The horizontal component of the ground anchors strength is equal to

$$(1{,}200 \text{ lbs/in})(\cos 45°) = 848 \text{ lb/in}$$

The manufactured home industry gives an allowable lateral manufactured home movement of 3 inches. So the total lateral strength of a ground anchor is (3 in) (848 lbs) = 2,544 lbs.

$$\text{Number of ground anchors needed} = \frac{\textit{lateral load}}{\textit{anchors lateral capacity}}$$

$$\text{Number of ground anchors needed} = \frac{(313 \text{ lb})(60 \text{ ft})}{2.544 \text{ lbs}} = 8 \text{ anchors per side}$$

$$\text{Calculate ground anchor spacing} = \frac{60 \text{ ft}}{(8\text{-}1)} = 8.5 \text{ ft}$$

The anchor strapping should attach into a wall stud; therefore, anchor spacing must be adjusted to 16-inch increments.

Both uplift and overturning failure modes are resisted by the vertical strength of ground anchors. The uplift forces will be resisted by all the ground anchors and the overturning moment will be resisted only by the windward ground anchors.

For the worst uplift of the vertical failure mode, load combination 7 (refer to Table F-6) governs. However, the maximum net uplift is 16 plf downward, which means that overturning will govern the uplift requirements.

For the overturning failure mode, load combination 7 (refer to Table F-10) governs for wind perpendicular to the roof ridge. Overturning moment is only resisted by the windward anchors. Therefore, the total vertical load each anchor will have to resist is

$$\frac{\dfrac{(\textit{overturning moment})(\textit{length of home})}{\textit{moment arm}}}{\textit{number of anchors per side}} = \frac{\dfrac{(979 \text{ ft-lbs})(60 \text{ ft})}{12 \text{ ft}}}{8 \text{ anchors}}$$

$$= 612 \text{ lbs per anchor}$$

The vertical component of the anchor stiffness equals

$$(1{,}200 \text{ lbs/in})(\cos 45) = 848 \text{ lbs/in}$$

The manufactured home industry gives an allowable vertical movement of 2 inches. This results in a vertical strength per anchor equal to

$$(2 \text{ in})(848 \text{ lbs/in}) = 1{,}697 \text{ lbs per anchor}$$

This is more than the strength needed by each anchor to resist the overturning moment.

The anchor strapping should attach into a wall stud and, therefore, anchor spacing must be adjusted to 16-inch increments. Place anchors at each end of the home and space at 72 inches.

For the overturning case, the connection of the straps to the stud and the ground anchor embedment is based on MWFRS pressures. However, although it would likely not govern, to be thorough, the uplift only condition using C&C pressures should be checked for these two anchorages (straps to studs and anchors in ground).

Step 5: Specify Connections and Framing Methods Along with Component Dimensions to Satisfy Load Conditions

The CMU pier and ground anchor foundation will consist of 16 dry-stack, 16-inch by 8-inch block piers with a minimum of a 1/4-inch thick surface bonded mortar and 24-inch square, 10-inch deep footings. Ground anchors will be placed at 45-degree angles at each end of the manufactured home and spaced at 72 inches.

Step 6: Note All Design Assumptions and Details on Drawings

Refer to pre-engineering foundation design drawings contained in Appendix H and specifications presented in Chapter 10 herein as to how to adequately document assumptions and detail drawings.

G. Wind Zone Comparisons (HUD's MHCSS and FEMA 85)

G.1 Background

HUD's *Manufactured Home Construction and Safety Standards* (MHCSS; 24 CFR 3280) and its *Model Manufactured Home Installation Standards* (24 CFR 3285) categorize the United States and many of its territories and protectorates into three wind zones: Zone I, Zone II, and the highest wind zone, Zone III.

FEMA 85, NFPA 225 *Model Manufactured Home Installation Standard*, and NFPA 501 S*tandard on Manufactured Housing* categorize the U.S. into four wind zones: Zone I, Zone II, Zone III, and the highest wind zone, Zone IV. However, to avoid confusion, in this appendix Zones 1, 2, 3, and 4 will be used to distinguish the NFPA zones from the HUD zones.

This appendix explains the differences between the wind provisions contained in the HUD standards and those contained in FEMA 85 and the NFPA standards.

G.2 Wind Provisions

The HUD standards, FEMA 85, and the NFPA standards all contain wind provisions based on ASCE 7, *Minimum Design Loads for Buildings and Other Structures*; however, they are not all based on the same edition of ASCE 7. HUD documents are based on a modified version of the 1988 edition of ASCE 7. FEMA 85 and the NFPA standards are based on more recent editions. The wind loads used to design FEMA 85 foundations comply with ASCE 7-02; the NFPA standards reference ASCE 7-05.

Only minor differences exist between the wind provisions of ASCE 7-05 and ASCE 7-02; however, the wind provisions of both ASCE 7-05 and ASCE 7-02 differ greatly from the wind provisions of ASCE 7-88.

Two major differences exist between ASCE 7-88 and ASCE 7-05. The basic wind speed map (Figure 6-1) in ASCE 7-88 was completely redrawn in 1995 and revised in 1998. The newer maps show high-wind zones extending much farther inland than those shown on the 1988 map. Also, the basic wind speeds are based on different averaging times. The 1988 edition of ASCE 7 uses

fastest mile wind speeds; ASCE 7-02 and 7-05 use 3-second gust wind speeds. The wind speeds in the older standard are numerically less than those in the contemporary standards. For example, ASCE 7-88 required buildings in the interior portion of the U.S. to be designed for a 70-mph (fastest mile) wind speed; ASCE 7-02 and 7-05 place the interior portions of the U.S. in a 90-mph (3-second gust) wind speed area. While the wind speeds are numerically greater, the design wind loads are often not greater and, in some areas, the wind loads are less.

G.3 Wind Zones

HUD regulates wind zones as:

HUD Zone II: Areas where the basic wind speed is 100 mph (fastest mile)

HUD Zone III: Areas where the basic wind speed is 110 mph (fastest mile)

HUD Zone I includes all areas not identified as either HUD Zone II or HUD Zone III and is not associated with a specific wind speed.

FEMA 85 and the NFPA Codes Zones identify wind zones as:

Zone 1: Areas bounded by the 90-mph isotach[1] in ASCE 7-02 (ASCE 7-05 for the NFPA codes)

Zone 2: Areas between the 90-mph and the 110-mph isotachs

Zone 3: Areas between the 110-mph and the 130-mph isotachs

Zone 4: Areas between the 130-mph and the 150-mph isotachs

Figure G-1 shows the HUD wind speed map contained in 24 CFR 3280. Figure G-2 shows the wind speed map used for FEMA 85 and the NFPA standards.

Note that the 2006 IBC Section §1609.3.1 shows the relationship between fastest mile and 3-second gust wind speeds.

$$V_{fm} = (V_{3\,sec} - 10.5)/1.05$$

Where: V_{fm} = Fastest mile wind speed (mph)

$V_{3\,sec}$ = 3-second gust wind speed (mph)

1 An isotach is a line in a given surface connecting points with equal wind speeds.

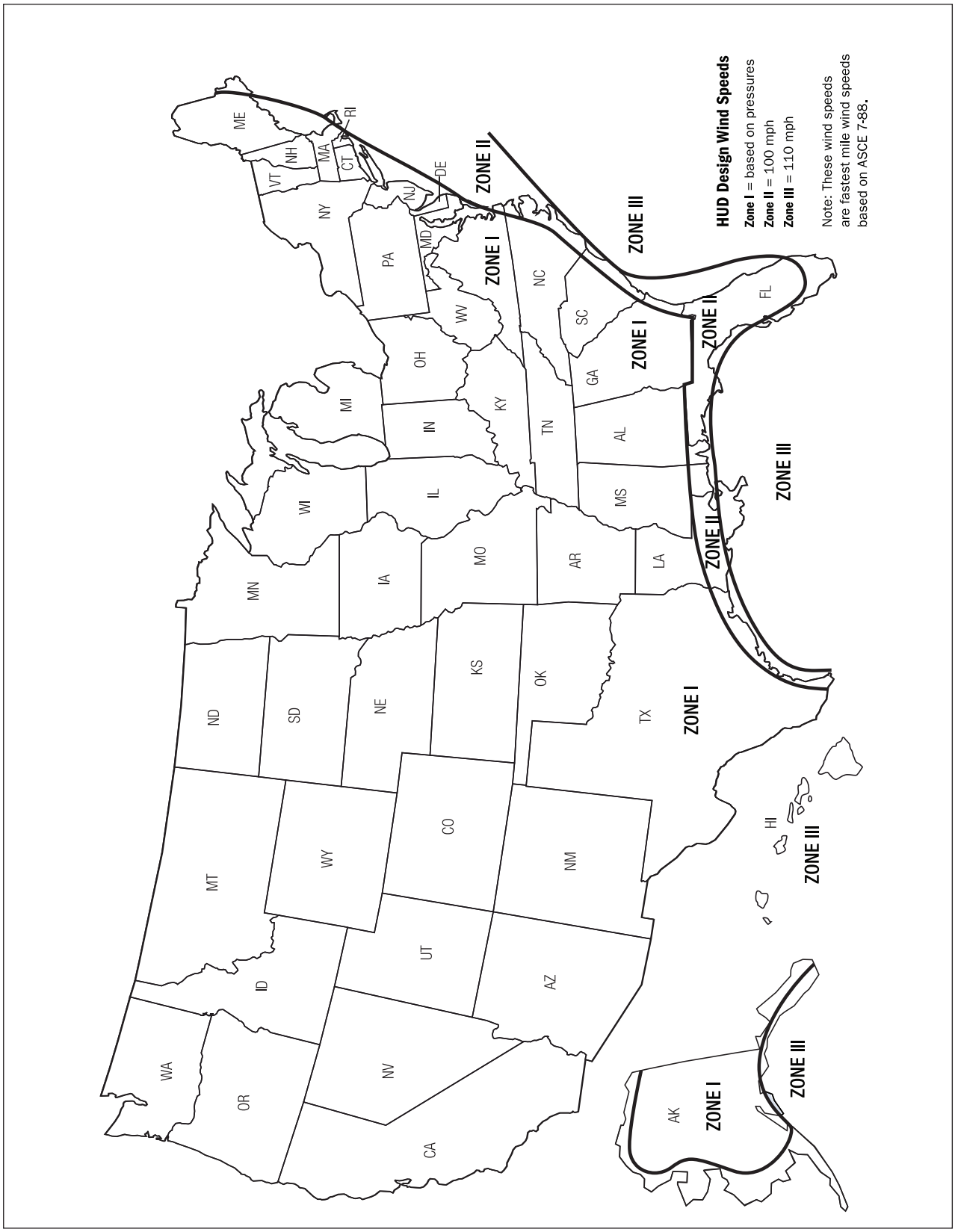


Figure G-1. Basic wind zone map for manufactured housing.

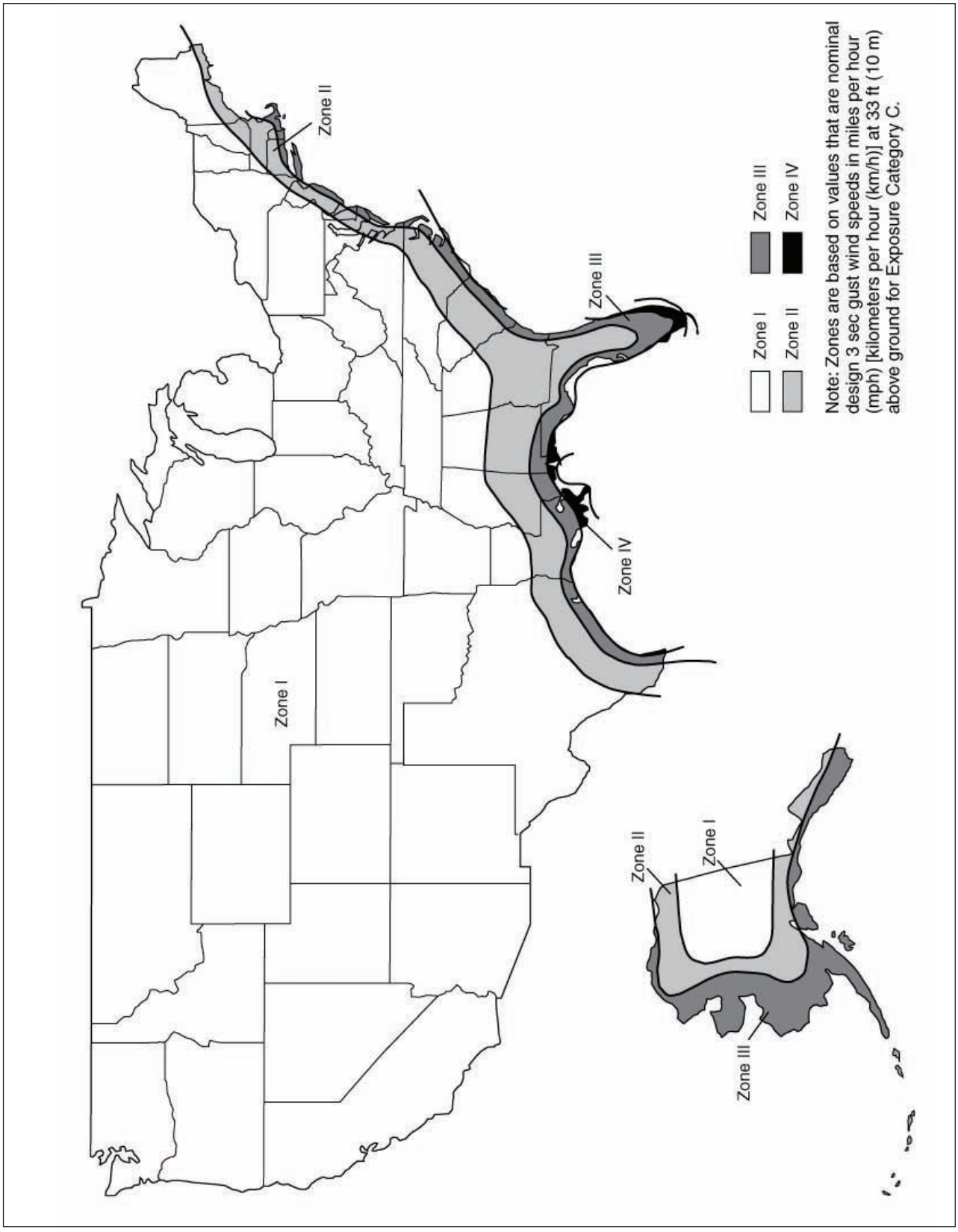

Zone II
Zone III
Zone IV
Zone I
Zone II
Zone I
Zone II
Zone III
Zone I
Zone II
Zone III
Zone IV
Note: Zones are based on values that are nominal design 3 sec gust wind speeds in miles per hour (mph) [kilometers per hour (km/h)] at 33 ft (10 m) above ground for Exposure Category C.

Figure G-2. NFPA 501 wind speed map.

G.4 Wind Speeds and County Lists

Wind speeds for communities are typically determined when building codes are adopted. The wind speeds should agree with those specified by ASCE 7, but are often decided upon by local officials particularly in large municipalities where several wind speeds apply.

For manufactured homes, wind zones are specified by the MHCSS and are listed by State and County. The MHCSS lists Counties contained in Wind Zones II and III. By default, all Counties not listed as either in Zone II or III are in HUD Zone I.

The following list identifies Counties by State for the various wind zones used in FEMA 85. Counties that are not listed or that are within the 90-mph isotach are in Zone 1.

Zone 4 (150 mph)

Florida: Broward, Martin, Miami-Dade, Monroe, Palm Beach

Louisiana: Parishes of Cameron, Lafourche, Plaquemines, St. Bernard, St. Mary, Terrebonne, Vermillion

Mississippi: Jackson

North Carolina: Brunswick, Carteret

Texas: Cameron

The U.S. Territories of Guam, Northern Mariana Islands, Puerto Rico, Trust Territory of the Pacific Islands, and the United States Virgin Islands

Zone 3 (130 mph)

American Samoa

Alabama: Baldwin, Mobile

Alaska: The coastal regions seaward of the 110-mph isotach on the ASCE 7 map

Connecticut: Middlesex, New London

Florida: Bay, Brevard, Calhoun, Charlotte, Citrus, Collier, DeSoto, Dixie, Duval, Escambia, Flagler, Gulf, Hendry, Hernando, Hillsborough, Holmes, Indian River, Jackson, Lee, Levy, Liberty, Manatee, Nassau, Okaloosa, Okeechobee, Pasco, Pinellas, Santa Rosa, Sarasota, St. Johns, St. Lucie, Taylor, Volusia, Wakulla, Walton, Washington

Georgia: Bryan, Camden, Chatham, Glynn, Liberty, McIntosh

Louisiana: Parishes of Assumption, Iberia, Lafayette, Orleans, St. Charles, St. James, St. John the Baptist, St. Martin, St. Tammany

Maryland: Somerset, Worchester

Massachusetts: Barnstable, Bristol, Dukes, Nantucket, Plymouth

Mississippi: George, Greene, Hancock, Harrison, Pearl River, Perry, Stone

New Jersey: Atlantic, Cape May, Ocean

New York: Nassau, Suffolk

North Carolina: Beaufort, Camden, Chowan, Columbus, Craven, Currituck, Dare, Hyde, Jones, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, Washington

Rhode Island: Bristol, Kent, Newport, Washington

South Carolina: Beaufort, Charleston, Georgetown, Horry

Texas: Brazoria, Calhoun, Chambers, Galveston, Jefferson, Kenedy, Kleberg, Matagorda, Nueces, Refugio, San Patricio, Willacy

Virginia: Accomack, Northampton

Zone 2 (110 mph)

Alabama: Autauga, Barbour, Bibb, Bullock, Butler, Chambers, Chilton, Choctaw, Coffee, Conecuh, Coosa, Covington, Crenshaw, Dale, Dallas, Elmore, Escambia, Macon, Montgomery, Perry, Pike, Russell, Sumter, Tallapoosa, Washington, Wilcox

Connecticut: Fairfield, Hartford, Litchfield, New Haven, Tolland, Windham

Delaware: Kent, Sussex

Florida: Alachua, Baker, Bradford, Clay, Columbia, De Soto, Gadsden, Gilchrist, Glades, Hamilton, Hardee, Highlands, Jefferson, Lafayette, Lake, Leon, Madison, Marion, Orange, Osceola, Putnam, Polk, Seminole, Sumter, Suwannee, Union

Georgia: Appling, Atkinson, Bacon, Baker, Baldwin, Ben Hill, Berrien, Bibb, Bleckley, Brantley, Brooks, Bulloch, Burke, Calhoun, Charlton, Chattahoochee, Clay, Clinch, Coffee, Colquitt, Columbia, Cook, Crawford, Crisp, Decatur, Dodge, Dooly, Dougherty, Early, Echols, Effingham, Emanuel, Evans, Glascock, Grady, Hancock, Harris, Houston, Irwin, Jeff Davis, Jefferson, Jenkins, Johnson, Jones, Lamar, Lanier, Laurens, Lee, Long, Lowndes, Macon, Marion, McDuffie, Meriwether, Miller, Mitchell, Monroe, Montgomery, Muscogee, Peach, Pierce, Pike, Pulaski, Quitman, Randolph, Richmond, Schley, Screven, Seminole, Stewart, Sumter, Talbot, Tattnall,

Taylor, Telfair, Terrell, Thomas, Tift, Toombs, Treutlen, Troup, Turner, Twiggs, Upson, Ware, Warren, Washington, Wayne, Webster, Wheeler, Wilcox, Wilkinson, Worth

Hawaii: the entire state

Louisiana: Parishes of Acadia, Allen, Ascension, Avoyelles, Beauregard, Calcasieu, Catahoula, Concordia, East Baton Rouge, East Feliciana, Evangeline, Iberville, Jefferson Davis, Jefferson, Livingston, Pointe Coupee, Rapides, St. Helena, St. Landry, St. Martin, Tangipahoa, Vermilion, Vernon, Washington, West Baton Rouge, West Feliciana

Maine: Androscoggin, Cumberland, Hancock, Kennebec, Knox, Lincoln, Sagadahoc, Waldo, York

Maryland: Caroline, Dorchester, Queen Annes, Talbot, Wicomico

Massachusetts: Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, Suffolk, Worcester

Mississippi: Adams, Amite, Claiborne, Clarke, Copiah, Covington, Forrest, Franklin, Hinds, Jasper, Jefferson, Jefferson Davis, Jones, Kemper, Lamar, Lauderdale, Lawrence, Leake, Lincoln, Marion, Neshoba, Newton, Noxubee, Pike, Rankin, Scott, Simpson, Smith, Walthall, Wayne, Wilkinson, Winston

New Hampshire: Cheshire, Hillsborough, Merrimack, Rockingham, Strafford

New Jersey: Bergen, Burlington, Camden, Cumberland, Essex, Gloucester, Hudson, Mercer, Middlesex, Monmouth, Morris, Passaic, Salem, Somerset, Union

New York: Bronx, Kings, New York, Putnam, Queens, Richmond, Rockland, Westchester

North Carolina: Bertie, Bladen, Cumberland, Duplin, Edgecombe, Gates, Greene, Halifax, Harnett, Hertford, Hoke, Johnston, Lenior, Martin, Nash, Northampton, Pitt, Robeson, Sampson, Scotland, Wayne, Wilson

Pennsylvania: none

Rhode Island: Providence

South Carolina: Aiken, Allendale, Bamberg, Barnwell, Berkeley, Calhoun, Chesterfield, Clarendon, Colleton, Darlington, Dillon, Dorchester, Fairfield, Florence, Hampton, Jasper, Kershaw, Lancaster, Lee, Lexington, Marion, Marlboro, Orangeburg, Richland, Sumter, Williamsburg

Texas: Angelina, Atascosa, Austin, Bastrop, Bee, Brooks, Burleson, Caldwell, Colorado, De Witt, Duval, Fayette, Fort Bend, Goliad, Gonzales, Grimes, Guadalupe, Hardin, Harris, Hidalgo, Jackson, Jasper, Jim Hogg, Jim Wells, Karnes, Lavaca, Lee, Liberty, Live Oak, McMullen, Montgomery,

Newton, Orange, Polk, San Jacinto, Starr, Trinity, Tyler, Victoria, Walker, Waller, Washington, Webb, Wharton, Wilson, Zapata

Virginia: Gloucester, Isle of Wight, James City, Lancaster, Mathews, Middlesex, Northumberland, Southampton, Surry, York. Cities of Chesapeake, Hampton, Newport News, Norfolk, Suffolk, Virginia Beach

H. Pre-Engineered and Prescriptive Foundation Designs

Drawing No.	Title
GN-1.1	Recommended Foundation – General Notes
M-1	Single Unit Masonry Foundation Plan
M-2	Double Unit Masonry Foundation Plan
M-3	Masonry Wall Foundation Detail
M-4	End Wall Foundation Detail
WF-1	Single Unit Wood Framed Foundation Plan
WF-2	Double Unit Wood Framed Foundation Plan
WF-3	Wood Framed Foundation Detail
WF-4	Wood Framed Shear Wall Detail
BM-1.1	Single Unit Braced Masonry Pier Foundation Plan
BM-1.2	Braced Masonry Pier Detail
BM-2.1	Double Unit Braced Masonry Pier Foundation Plan
BM-2.2	Braced Masonry Pier Detail
HF-1.1	Single Unit Braced Wood H-Frame Foundation Plan
HF-1.2	Single Unit Wood H-Frame Detail
HF-2.1	Double Unit Braced Wood H-Frame Foundation Plan
HF-2.2	Double Unit Wood H-Frame Detail
GASP90-1.1	Single Unit Ground Anchor Foundation Plan
GASP90-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP90-2.1	Double Unit Ground Anchor Foundation Plan
GASP90-2.2	Ground Anchor and Pier Detail (Double Unit)
GASP110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GASP110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GASP110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GASP110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
GA90-1.1	Single Unit Ground Anchor Foundation Plan
GA90-1.2	Ground Anchor and Pier Detail (Single Unit)

Drawing No.	Title
GA90-2.1	Double Unit Ground Anchor Foundation Plan
GA90-2.2	Ground Anchor and Pier Detail (Double Unit)
GA110/130/150-1.1	Single Unit Ground Anchor Foundation Plan
GA110/130/150-1.2	Ground Anchor and Pier Detail (Single Unit)
GA110/130/150-2.1	Double Unit Ground Anchor Foundation Plan
GA110/130/150-2.2	Ground Anchor and Pier Detail (Double Unit)
APD-1.1	Alternative Pier Details for Flood Velocities Not Shown on Plans
AS-1.1	Lateral Ground Anchor Spacing
AS-1.2	Longitudinal Ground Anchor Spacing and Anchor Notes
SP-1/2.1	Single Unit Concrete Masonry Pier Foundation Plan
SP-1/2.2	Concrete Masonry Pier Details
SM-1/2.1	Single Unit Concrete Masonry Wall Foundation Plan
SM-1/2.2	Concrete Masonry Wall Foundation Detail
SWF-1/2.1	Single Unit Wood Framed Foundation Plan
SWF-1/2.2	Wood Framed Foundation Detail

Notes

1. These recommended foundation designs contain guidance for making manufactured homes, placed in Special Flood Hazard Areas, resistant to natural hazards. The designs do not cover all installations. Manufactured homes placed in the following areas are excluded:
   a. V zones
   b. Coastal A zones: Areas identified on FIRM as areas of Limited Moderate Wave Action (LIMWA) where conditions can produce breaking wave heights of 1.5 feet or greater.
   c. Floodways
   d. Areas with Flood Velocities over 5 feet per second
   e. Areas with Flood Depths over 3 feet
   f. Areas with Seismic Spectral Acceleration Constants S_s greater than 0.5g or S_1 greater than 0.15g
   g. Areas with ground snow loads greater than 40 pounds per square foot
   h. Installations with pier heights over 36 inches
   i. Manufactured homes weighing less than 25 psf
   j. Manufactured homes with frames spaced less than 95 inches
   k. Manufactured homes with endwall heights over 8 feet 2 inches
2. The foundation systems have been designed to resist loads specified in ASCE 7 *Minimum Design Loads for Buildings and Other Structures*. Any locally adopted code or ordinance with more stringent requirements shall govern.
3. Designs are provided as guidance for foundations that satisfy the recommended design criteria specified in Chapter 10. Selection of specific foundation type and final design must be made on the basis of individual site conditions, manufacturer installation instructions, and regulatory requirements.
4. Recommended foundation design is based on a 14-foot wide (single unit) and a 28-foot wide (double unit) manufactured home. These designs can be used with section widths up to 16 feet provided the spacing of fasteners connecting the home to the longitudinal foundation walls are reduced by the factor (14 divided by the actual section width).
5. Seismic resistant foundation designs provided (drawings SP, SM, SWF) are a suitable for homes placed in areas with Seismic Design Criteria D_0, D_1, D_2 and E with a basic wind speed of 90 mph (3-second gust) or less.
6. The foundations are depicted on flat sites. Where manufactured homes are placed on sloped lots, refer to NFPA 5000 Chapter 36.8 or IRC-2009 Sections R403.1.5 and R403.1.7 for additional requirements.
7. Soil bearing capacity shall be as required by the authority having jurisdiction. Where presumptive values are allowed, they shall be per NFPA 5000-2009 Table 36.3.4(a) IRC 2009 Table R401.4.1 or 24CFR Table 3285.202 as directed by the Building official.
8. Anchor performance shall be based on load testing and probabilistic analysis of anchors tested in both dry and saturated soils. Anchor design values shall be based on a maximum 10% lower exclusion limit and a minimum 90% confidence interval. Anchor spacing in these designs is based on a minimum stiffness of 1,200 pounds per inch for in-line anchors and 675 pounds per inch for anchors used with 11”x17” steel stabilizer plates. These stiffness values were determined from tests of 5-foot anchors conducted in saturated and unsaturated uniform (poorly graded) medium to fine grained sandy soils (soil class 4 A) in Kissimmee, Florida, July 2002. Torque and/or Standard penetration tests (ASTM D-1586-99) tests should be used in ground anchor selection.
9. Preload anchors a minimum of 500 pounds or as required to fully activate the resistance of the stabilizer plates and the anchor helices.
10. Anchor straps shall be galvanized, tested per ASTM D3953, and shall have a minimum allowable working load of 3,150 pounds and a minimum tensile strength of 4,725 pounds.
11. Concrete anchors shall provide a minimum allowable working load of 3,150 pounds and a minimum ultimate load of 4,725 pounds. Place concrete anchors a minimum of 3 inches away from all edges of footings.
12. Concrete masonry units shall be Type I or Type II per ASTM C90. Mortar shall be Type M, N, or S per ASTM C270.
13. Polyurethane based masonry adhesives may be used in place of Portland cement/lime mortar. Masonry adhesives used shall have been tested and certified by a nationally recognized agency as equivalent to Type M, O, and S Portland cement/lime masonry. Certification shall indicate that masonry adhesive is applicable to masonry construction designed in accordance with the requirements of IRC Section 606. Masonry adhesives shall be installed in strict accordance with the manufacture's instruction.
14. Grout shall be coarse aggregate and shall be apportioned per ASTM C476.
15. Surface bonded mortar shall meet ASTM C887-79a (2001) and ASTM C946-91 (2001).
16. Wind speed is a 3-second gust speed in miles per hour at 33 feet above ground in Exposure Category C.
17. Maximum anchor spacing is the spacing designed to limit manufactured home movement during a design event to 3” horizontal or 2” vertical. This criterion has historically been used by the manufactured housing industry.
18. End anchors shall be located no more than 2 feet from the ends of the home per 24 CFR Part 3280.306 (c)(2).
19. Flood vents required by the NFIP, in accordance with NFIP Section 60.3(c)(5), may be omitted for homes with non-structural skirting providing:
    - The skirting system will prevent differential flood depths from reaching 12 inches.
    - Performance of skirting under flood conditions is certified by a licensed professional engineer or architect.

Symbols and Abbreviations

ABS	- acrylonitrile butadiene styrene	o.c.	- on center
CMU	- concrete masonry unit	psf	- pounds per square foot
fps	- feet per second	psi	- pounds per square inch
f_b	- Bending strength (wood)	PL	- plate
$f_{c\parallel}$	- compressive strength parallel to grain (wood)	PT	- preservative treated
$f_{c\perp}$	- compressive strength perpendicular to grain (wood)	Ss	- spectral response acceleration at short periods
f'_c	- compressive strength (concrete)	S_1	- spectral response acceleration at a period of 1 second
f_t	- tensile strength parallel to grain (wood)	T and B	- top and bottom
f_v	- shear strength parallel to grain (wood)	Typ.	- typical
f_y	- yield strength of reinforcing steel	a > b	- a is greater than or equal to b
g	- gravitational force	$a \geq b$	- a is less than or equal to b
max	- maximum	$a \leq b$	- a is less than b
mph	- miles per hour		

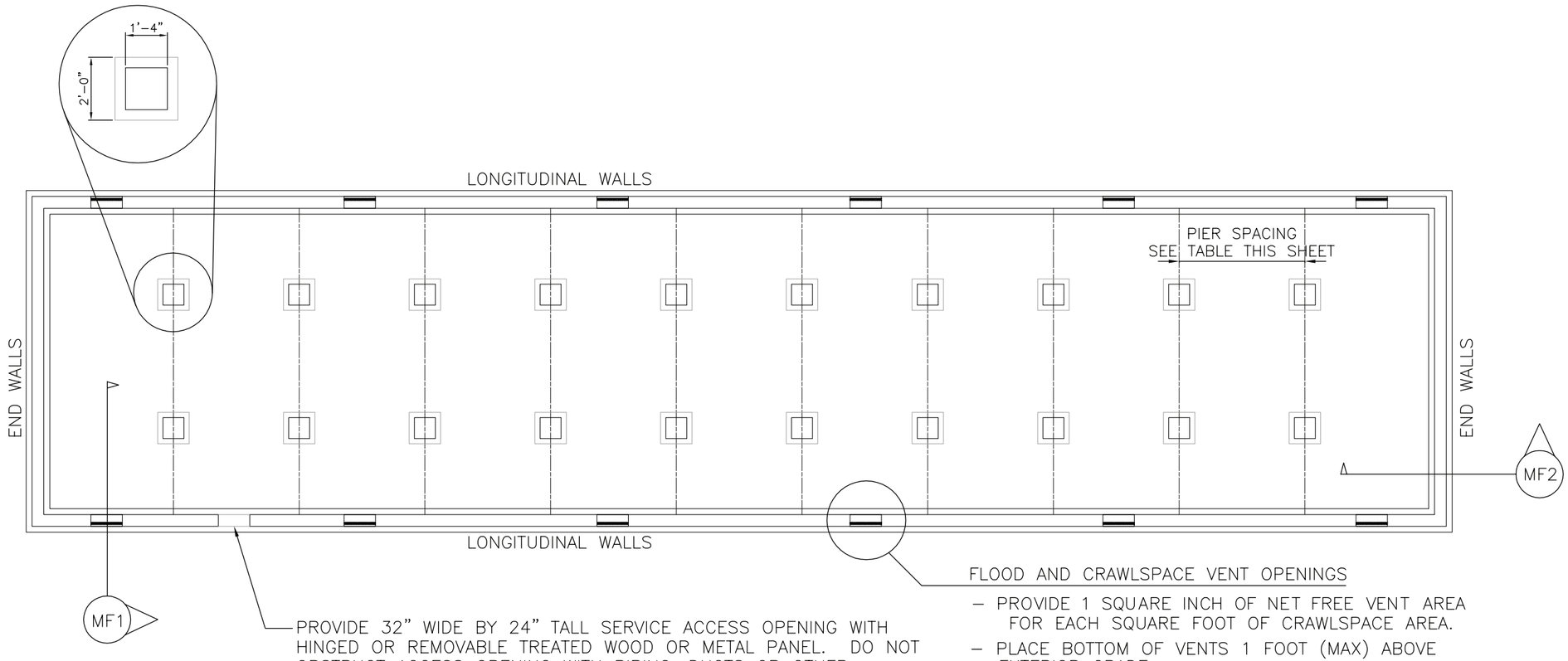
Material Specifications

1. All exposed hardware shall be hot dipped galvanized per ASTM A-153. Nails and hardware in contact with framing or plywood with preservative treatment concentration exceeding 0.40 pound per cubic foot shall be stainless steel.
2. All concrete shall be a mixture of Portland Cement, water, and aggregate and shall be proportioned to provide a minimum 3,000 psi 28-day compressive strength (f'_c). Portland Cement shall be per ASTM C150.
3. Reinforcing steel shall be deformed bars per ASTM A615, A617 or A706 and shall have a minimum 60 ksi yield strength (f_y). Lap splices in reinforcing steel a minimum of 36 bar diameters.
4. All wood below the BFE and not in contact with the soil (framing, shims, etc.) shall meet or exceed NFIP flood resistant material requirements. One acceptable method is to provide rot and insect resistance that meets or exceeds protection provided by ACQ (alkaline copper quaternary) at a retention of 0.25 pounds per cubic foot. See FEMA Technical Bulletin 2 for additional guidance.
5. All wood shall be of a species recognized for structural use by the authority having jurisdiction and shall provide the minimum design values as follows:

f_b	$\geq$	975 psi
f_t	$\geq$	550 psi
f_v	$\geq$	90 psi
$f_{c\perp}$	$\geq$	565 psi
$f_{c\parallel}$	$\geq$	1,450 psi

6. Foundation wall sheathing shall be American Plywood Association (APA) rated panels and constructed with cross laminated full width veneers that conform to Voluntary Product Standard PSI-95. Sheathing shall be pressure preservative treated with ACQ-B (ammoniacal copper quat) Type B or D to a minimum retention of 0.25 pounds per cubic foot.

RECOMMENDED FOUNDATION-GENERAL NOTES



PROVIDE 32" WIDE BY 24" TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS OR OTHER EQUIPMENT.

FLOOD AND CRAWLSPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

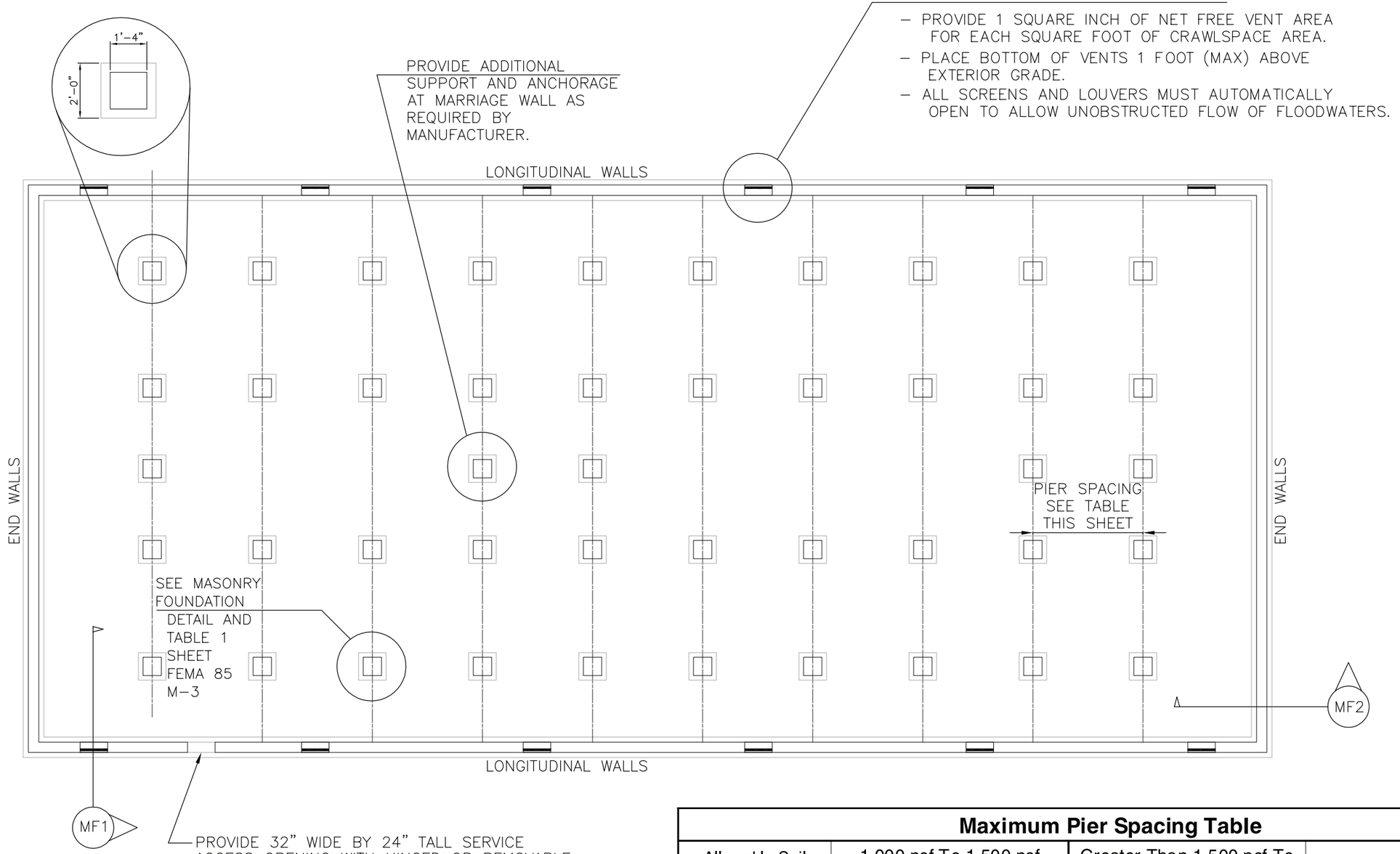
Maximum Pier Spacing Table

Allowable Soil Bearing Pressure	1,000 psf To 1,500 psf			Greater Than 1,500 psf To 2,000 psf			Greater Than 2,000		
Snow Load (psf)	20	30	40	20	30	40	20	30	40
Pier Spacing	5'-8"	5'-0"	4'-6"	8'-0"	8'-0"	7'-4"	8'-0"	8'-0"	8'-0"

SINGLE UNIT MASONRY FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


1'-4"
2'-0"
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL AS REQUIRED BY MANUFACTURER.
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
LONGITUDINAL WALLS
END WALLS
END WALLS
PIER SPACING SEE TABLE THIS SHEET
SEE MASONRY FOUNDATION DETAIL AND TABLE 1 SHEET FEMA 85 M–3
MF2
LONGITUDINAL WALLS
MF1
PROVIDE 32" WIDE BY 24" TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS, OR OTHER EQUIPMENT.

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure	1,000 psf To 1,500 psf			Greater Than 1,500 psf To 2,000 psf			Greater Than 2,000		
Snow Load (psf)	20	30	40	20	30	40	20	30	40
Pier Spacing	5'-8"	5'-0"	4'-6"	8'-0"	8'-0"	7'-4"	8'-0"	8'-0"	8'-0"

DOUBLE UNIT MASONRY FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

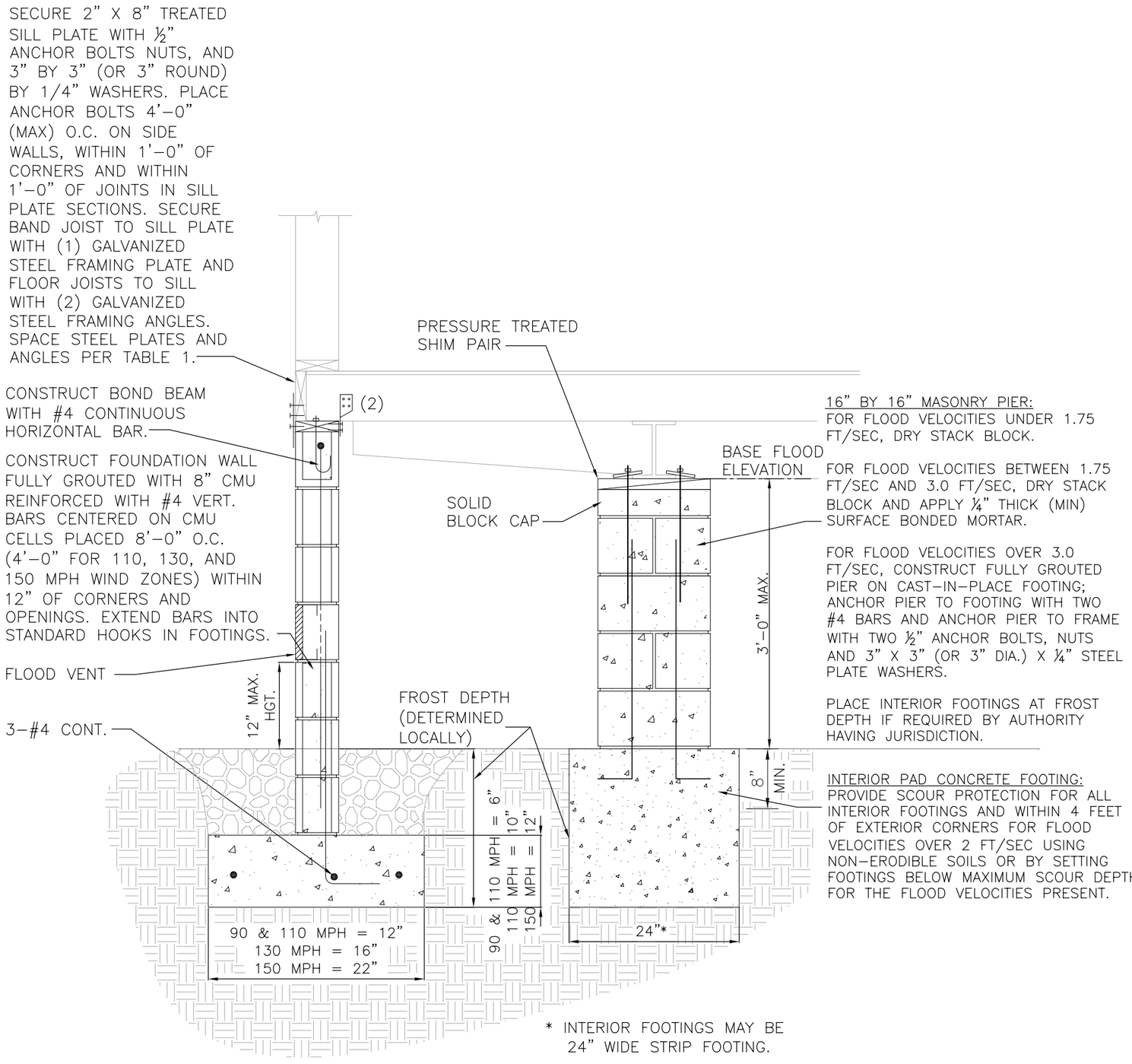

SECURE 2" X 8" TREATED SILL PLATE WITH ½" ANCHOR BOLTS NUTS, AND 3" BY 3" (OR 3" ROUND) BY 1/4" WASHERS. PLACE ANCHOR BOLTS 4'–0" (MAX) O.C. ON SIDE WALLS, WITHIN 1'–0" OF CORNERS AND WITHIN 1'–0" OF JOINTS IN SILL PLATE SECTIONS. SECURE BAND JOIST TO SILL PLATE WITH (1) GALVANIZED STEEL FRAMING PLATE AND FLOOR JOISTS TO SILL WITH (2) GALVANIZED STEEL FRAMING ANGLES. SPACE STEEL PLATES AND ANGLES PER TABLE 1.
PRESSURE TREATED SHIM PAIR
(2)
CONSTRUCT BOND BEAM WITH #4 CONTINUOUS HORIZONTAL BAR.
CONSTRUCT FOUNDATION WALL FULLY GROUTED WITH 8" CMU REINFORCED WITH #4 VERT. BARS CENTERED ON CMU CELLS PLACED 8'–0" O.C. (4'–0" FOR 110, 130, AND 150 MPH WIND ZONES) WITHIN 12" OF CORNERS AND OPENINGS. EXTEND BARS INTO STANDARD HOOKS IN FOOTINGS.
FLOOD VENT
12" MAX. HGT.
3–#4 CONT.
FROST DEPTH (DETERMINED LOCALLY)
SOLID BLOCK CAP
BASE FLOOD ELEVATION
3'–0" MAX.
8" MIN.
90 & 110 MPH = 6"
110 MPH = 10"
150 MPH = 12"
90 & 110 MPH = 12"
130 MPH = 16"
150 MPH = 22"
24"*
16" BY 16" MASONRY PIER:
FOR FLOOD VELOCITIES UNDER 1.75 FT/SEC, DRY STACK BLOCK.
FOR FLOOD VELOCITIES BETWEEN 1.75 FT/SEC AND 3.0 FT/SEC, DRY STACK BLOCK AND APPLY ¼" THICK (MIN) SURFACE BONDED MORTAR.
FOR FLOOD VELOCITIES OVER 3.0 FT/SEC, CONSTRUCT FULLY GROUTED PIER ON CAST–IN–PLACE FOOTING; ANCHOR PIER TO FOOTING WITH TWO #4 BARS AND ANCHOR PIER TO FRAME WITH TWO ½" ANCHOR BOLTS, NUTS AND 3" X 3" (OR 3" DIA.) X ¼" STEEL PLATE WASHERS.
PLACE INTERIOR FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.
INTERIOR PAD CONCRETE FOOTING:
PROVIDE SCOUR PROTECTION FOR ALL INTERIOR FOOTINGS AND WITHIN 4 FEET OF EXTERIOR CORNERS FOR FLOOD VELOCITIES OVER 2 FT/SEC USING NON–ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.
* INTERIOR FOOTINGS MAY BE 24" WIDE STRIP FOOTING.

Table 1 - Floor Framing Connector Schedule		
	Side Walls[1]	
Wind Speed	Single Unit	Double Unit
90 mph	8'- 0"	8'- 0"
110 mph	8'- 0"	8'- 0"
130 mph	4'- 0"	4'- 0"
150 mph	4'- 0"	4'- 0"
	Interior Shear Walls & End Walls [2]	
Wind Speed	Single Unit	Double Unit
90 mph	4'- 0"	6'- 0"
110 mph	2'- 6"	5'- 0"
130 mph	2'- 0"	4'- 0"
150 mph	2'- 4" (2)	2'- 4"

[1] Connector spacing is based on plate anchors capable of resisting (un-factored) 515# uplift and in-plane lateral loads and angle anchors each capable of resisting (un-factored) 340# uplift loads. Locate plate and angle anchors within 1'-4" of sill plate anchor bolts.

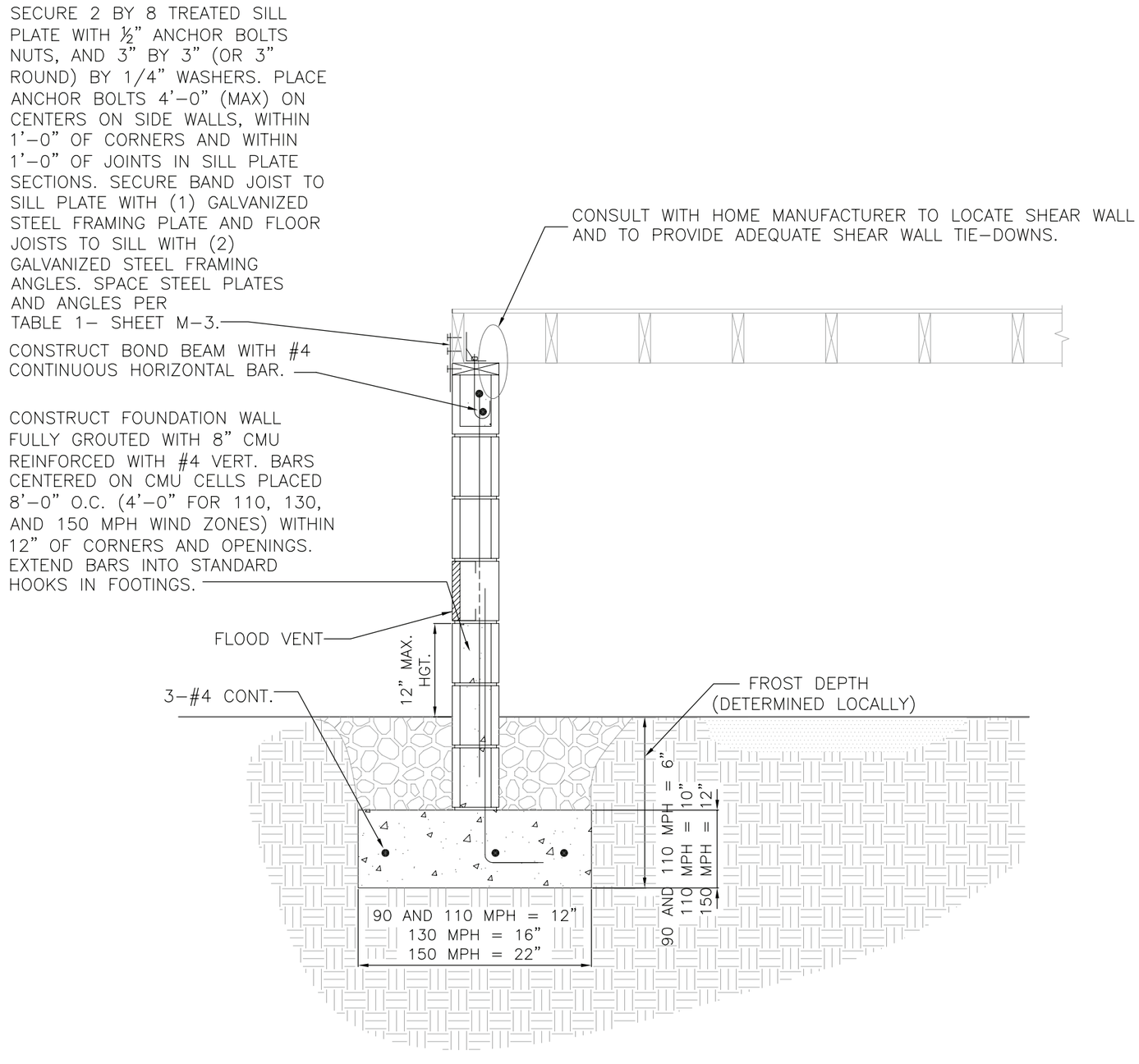
[2] Connector spacing is based on plate anchors capable of resisting (un-factored) 515# in-plane lateral load and angle anchors capable of resisting (un-factored) 850# in plane lateral loads.

MF1

MASONRY WALL FOUNDATION DETAIL

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

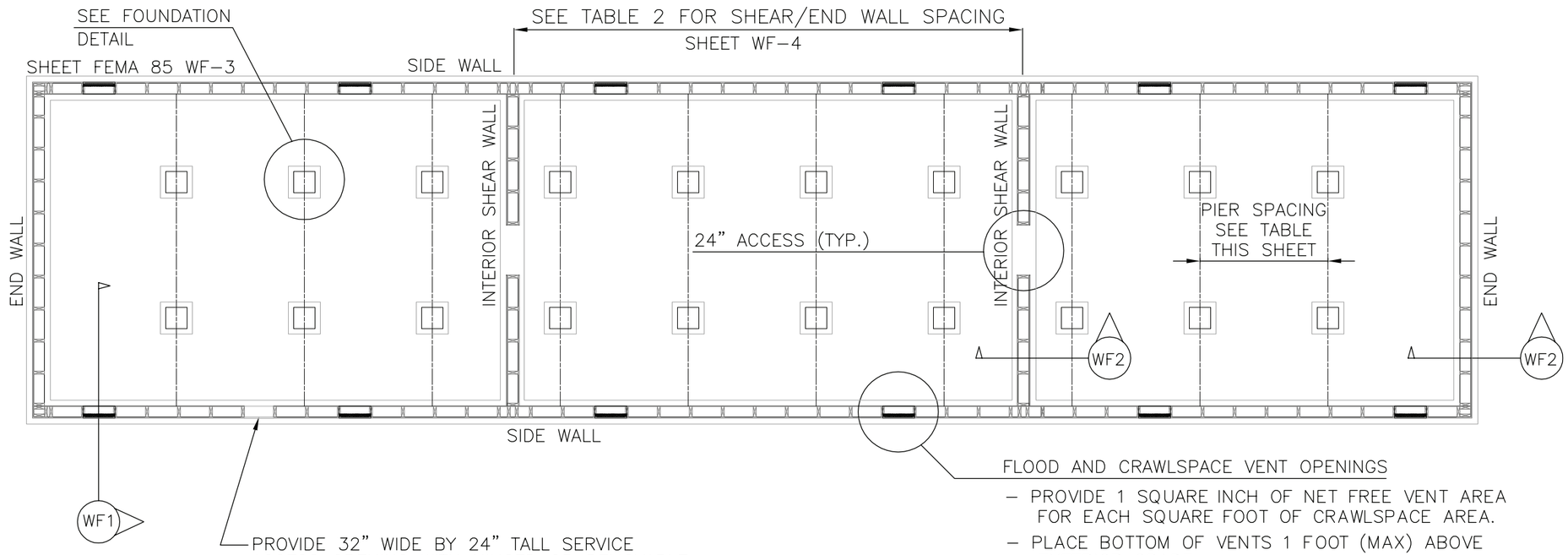

SECURE 2 BY 8 TREATED SILL PLATE WITH ½" ANCHOR BOLTS NUTS, AND 3" BY 3" (OR 3" ROUND) BY 1/4" WASHERS. PLACE ANCHOR BOLTS 4'–0" (MAX) ON CENTERS ON SIDE WALLS, WITHIN 1'–0" OF CORNERS AND WITHIN 1'–0" OF JOINTS IN SILL PLATE SECTIONS. SECURE BAND JOIST TO SILL PLATE WITH (1) GALVANIZED STEEL FRAMING PLATE AND FLOOR JOISTS TO SILL WITH (2) GALVANIZED STEEL FRAMING ANGLES. SPACE STEEL PLATES AND ANGLES PER TABLE 1– SHEET M–3.
CONSULT WITH HOME MANUFACTURER TO LOCATE SHEAR WALL AND TO PROVIDE ADEQUATE SHEAR WALL TIE–DOWNS.
CONSTRUCT BOND BEAM WITH #4 CONTINUOUS HORIZONTAL BAR.
CONSTRUCT FOUNDATION WALL FULLY GROUTED WITH 8" CMU REINFORCED WITH #4 VERT. BARS CENTERED ON CMU CELLS PLACED 8'–0" O.C. (4'–0" FOR 110, 130, AND 150 MPH WIND ZONES) WITHIN 12" OF CORNERS AND OPENINGS. EXTEND BARS INTO STANDARD HOOKS IN FOOTINGS.
FLOOD VENT
12" MAX. HGT.
3–#4 CONT.
FROST DEPTH (DETERMINED LOCALLY)
90 AND 110 MPH = 6"
110 MPH = 10"
150 MPH = 12"
90 AND 110 MPH = 12"
130 MPH = 16"
150 MPH = 22"

MF2

END WALL FOUNDATION DETAIL

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


SEE FOUNDATION DETAIL
SHEET FEMA 85 WF-3
SEE TABLE 2 FOR SHEAR/END WALL SPACING
SHEET WF-4
SIDE WALL
END WALL
INTERIOR SHEAR WALL
24" ACCESS (TYP.)
PIER SPACING SEE TABLE THIS SHEET
WF2
WF1
PROVIDE 32" WIDE BY 24" TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS OR OTHER EQUIPMENT.
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

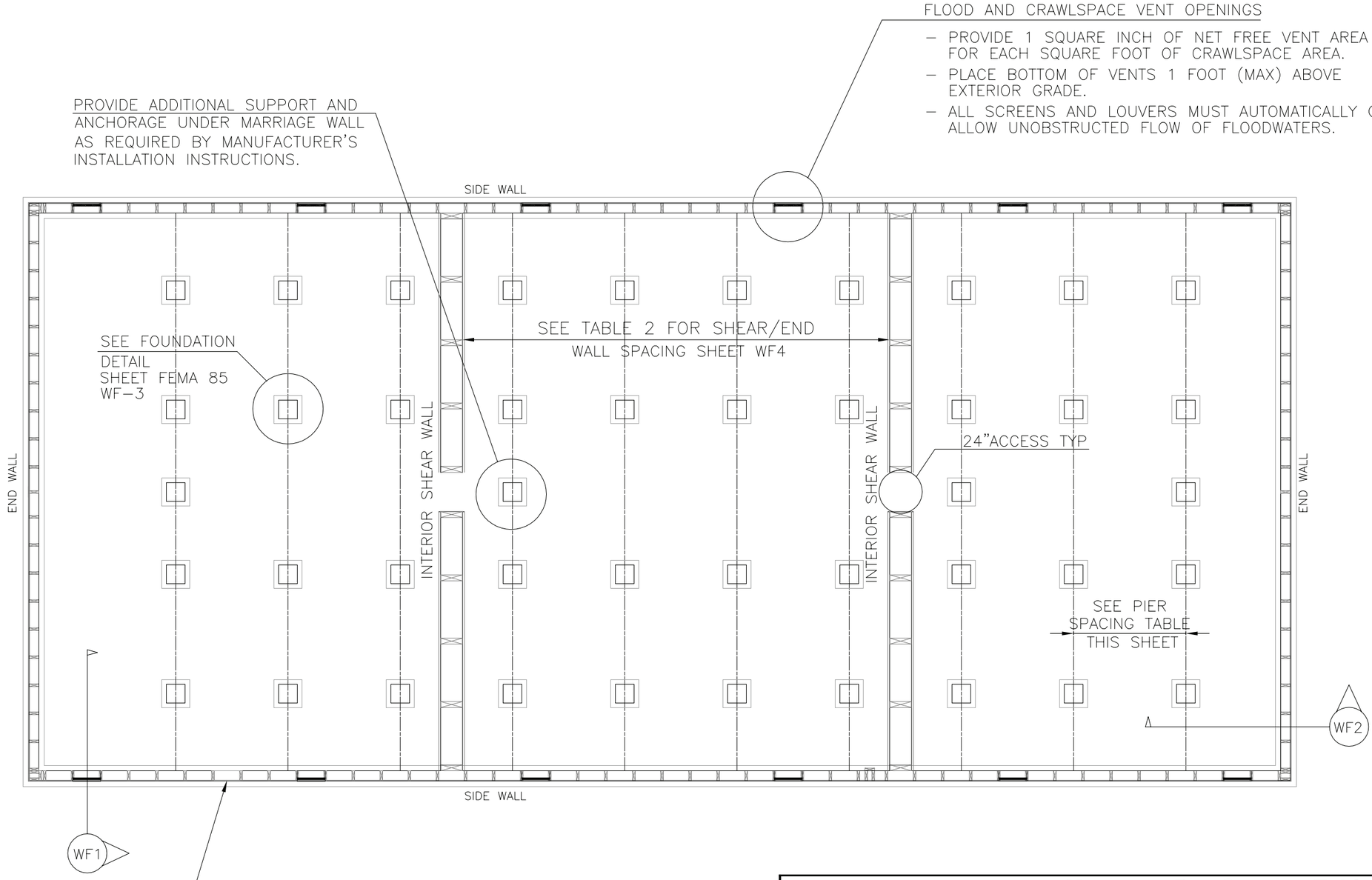
Maximum Pier Spacing Table

Allowable Soil Bearing Pressure	1,000 psf To 1,500 psf			Greater than 1,500 psf To 2,000 psf			Greater than 2,000 psf		
Snow Load (psf)	20	30	40	20	30	40	20	30	40
Pier Spacing	5'-8"	5'-0"	4'-6"	8'-0"	8'-0"	7'-4"	8'-0"	8'-0"	8'-0"

SINGLE UNIT WOOD FRAMED FOUNDATION PLAN

NOT TO SCALE - INTERIOR SHEAR WALL LOCATION FOR 90 AND 110 MPH DESIGN WIND SPEED

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

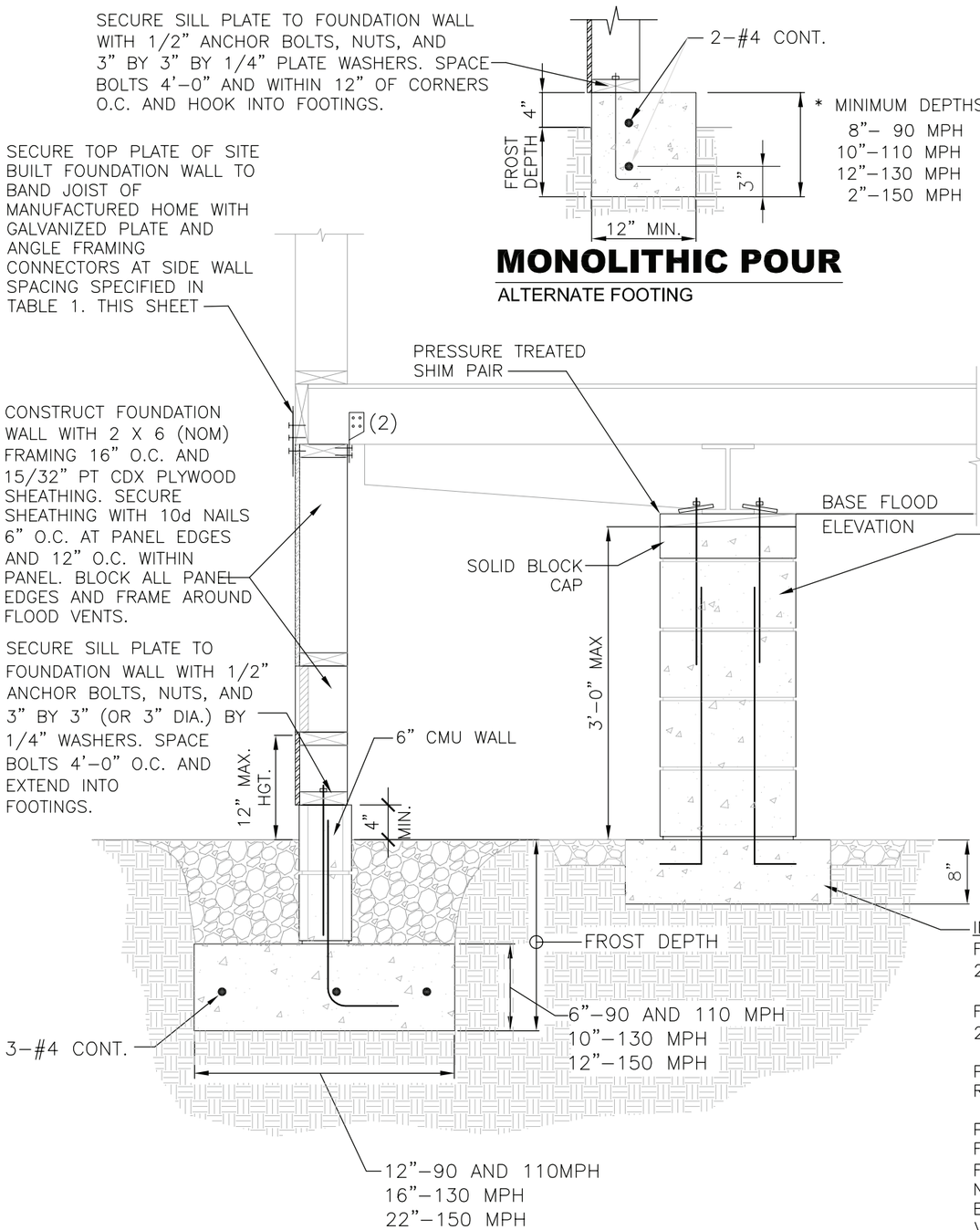

FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER MARRIAGE WALL AS REQUIRED BY MANUFACTURER'S INSTALLATION INSTRUCTIONS.
SIDE WALL
SEE FOUNDATION DETAIL SHEET FEMA 85 WF–3
SEE TABLE 2 FOR SHEAR/END WALL SPACING SHEET WF4
INTERIOR SHEAR WALL
INTERIOR SHEAR WALL
24"ACCESS TYP
END WALL
END WALL
SEE PIER SPACING TABLE THIS SHEET
WF2
SIDE WALL
WF1
PROVIDE 32" WIDE BY 24" TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS, OR OTHER EQUIPMENT.

Maximum Pier Spacing Table									
Allowable Soil Bearing Pressure	1,000 psf To 1,500 psf			Greater than1,500 psf To 2,000 psf			Greater than 2,000 psf		
Snow Load (psf)	20	30	40	20	30	40	20	30	40
Pier Spacing	5'-8"	5'-0"	4'-6"	8'-0"	8'-0"	7'-4"	8'-0"	8'-0"	8'-0"

DOUBLE UNIT WOOD FRAMED FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


SECURE SILL PLATE TO FOUNDATION WALL WITH 1/2" ANCHOR BOLTS, NUTS, AND 3" BY 3" BY 1/4" PLATE WASHERS. SPACE BOLTS 4'–0" AND WITHIN 12" OF CORNERS O.C. AND HOOK INTO FOOTINGS.
2–#4 CONT.
FROST DEPTH
4"
3"
12" MIN.
* MINIMUM DEPTHS
8"– 90 MPH
10"–110 MPH
12"–130 MPH
2"–150 MPH
* INCREASE DEPTH OF FOOTING AS REQUIRED TO PLACE BOTTOM OF FOOTING AT OR BELOW DESIGN FROST DEPTH
SECURE TOP PLATE OF SITE BUILT FOUNDATION WALL TO BAND JOIST OF MANUFACTURED HOME WITH GALVANIZED PLATE AND ANGLE FRAMING CONNECTORS AT SIDE WALL SPACING SPECIFIED IN TABLE 1. THIS SHEET
PRESSURE TREATED SHIM PAIR
(2)
CONSTRUCT FOUNDATION WALL WITH 2 X 6 (NOM) FRAMING 16" O.C. AND 15/32" PT CDX PLYWOOD SHEATHING. SECURE SHEATHING WITH 10d NAILS 6" O.C. AT PANEL EDGES AND 12" O.C. WITHIN PANEL. BLOCK ALL PANEL EDGES AND FRAME AROUND FLOOD VENTS.
BASE FLOOD ELEVATION
SOLID BLOCK CAP
3'–0" MAX
SECURE SILL PLATE TO FOUNDATION WALL WITH 1/2" ANCHOR BOLTS, NUTS, AND 3" BY 3" (OR 3" DIA.) BY 1/4" WASHERS. SPACE BOLTS 4'–0" O.C. AND EXTEND INTO FOOTINGS.
6" CMU WALL
12" MAX. HGT.
4" MIN.
8"
FROST DEPTH
6"–90 AND 110 MPH
10"–130 MPH
12"–150 MPH
3–#4 CONT.
12"–90 AND 110MPH
16"–130 MPH
22"–150 MPH

MONOLITHIC POUR

ALTERNATE FOOTING

MASONRY PIER:

FOR FLOOD VELOCITIES UNDER 1.75 FT/SEC, CONSTRUCT 16"X16" PIER WITH DRY–STACK BLOCK.

FOR FLOOD VELOCITIES BETWEEN 1.75 FT/SEC AND 3.0 FT/SEC, CONSTRUCT 16"X16" PIER WITH DRY–STACK BLOCK AND APPLY ¼" THICK (MIN) SURFACE BONDED MORTAR.

FOR FLOOD VELOCITIES OVER 2.5 FT/SEC, CONSTRUCT 8"X16" FULLY GROUTED PIER ON CAST–IN–PLACE FOOTING; ANCHOR PIER TO FOOTING WITH TWO #4 BARS AND ANCHOR PIER TO FRAME WITH TWO ½" ANCHOR BOLTS, NUTS AND 3"X3" (OR 3" DIA.) X ¼" STEEL PLATE WASHERS.

PLACE INTERIOR FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

(PIER SHOWN FOR FLOOD VELOCITIES UP TO 5 FT/SEC)

INTERIOR PAD CONCRETE FOOTING:

FOR FLOOD VELOCITIES UNDER 2 FT/SEC, SET 24"X24"X4" THICK CAST–IN–PLACE FOOTING.

FOR FLOOD VELOCITIES OVER 2 FT/SEC, POUR 24"X24"X8" THICK CAST–IN–PLACE FOOTING.

PLACE INTERIOR FOOTINGS AT FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION FOR ALL INTERIOR FOOTINGS AND WITHIN 4 FEET OF CORNERS FOR FLOOD VELOCITIES OVER 2 FT/SEC USING NON–ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

Table 1 - Side Wall Framing Connector Schedule [1]

Wind Speed	Single Unit	Double Unit
90 mph	8'–0"	8'–0"
110 mph	8'–0"	8'–0"
130 mph	4'–0"	4'–0"
150 mph	4'–0"	4'–0"

[1] INSTALL PLATE AND ANCHOR CONNECTORS IN PAIRS. PLATE AND ANCHOR CONNECTORS MAY BE OFFSET A MAXIMUM OF 8 INCHES TO REDUCE POTENTIAL FOR SPLITTING. CONNECTOR SPACING IS BASED ON PLATE AND ANGLE CONNECTOR CAPACITIES OF 330 AND 455 POUNDS, RESPECTIVELY. FOR REFERENCE, CONNECTION DESIGNS ARE BASED ON SIMPSON MODEL LTP4 PLATE CONNECTORS AND SIMPSON MODEL H3 ANGLE CONNECTORS.

Table 2 – End/Shear Wall Spacing and Connector Schedule [1,4]

Configuration	Home Width(Ft)	Design Wing Speed Max. Shear/End Wall Spacing (Ft.) [2] / Number of Connectors Per Section [3]			
		90 mph	110 mph	130 mph	150 mph
Single Unit	12	20	16	12	8
		5	5	6	5
	14	20	16	12	8
		5	6	6	5
	16	28	20	16	12
		7	7	7	7
Double Unit	24	36	24	20	16
		5	4	5	5
	28	44	32	20	16
		6	6	5	5
	32	40	32	24	20
		5	6	6	7

[1]Table is applicable to single and double unit manufactured homes with 8ft. wall height, roof slopes between 3:12 and 7:12 located in the special flood hazard area with flood velocities not exceeding 5 fps.

[2]Shear wall spacing is based on the wood frame foundations shear and end walls constructed as specified in Table 3.17D of the 2001 *Wood Framed Construction Manual.*

[3]Install plate and anchor connectors in pairs. Plate and anchor connectors may be offset a maximum of 8 inches to reduce potential for splitting. The number of connectors fastening the site built foundation wall to the manufactured home is based on angle and plate connectors installed in pairs and having a capacity of 395 and 515 pounds, respectively. For reference, connection designs are based on Simpson Model A34 angle connectors and LTP4 plate connectors.

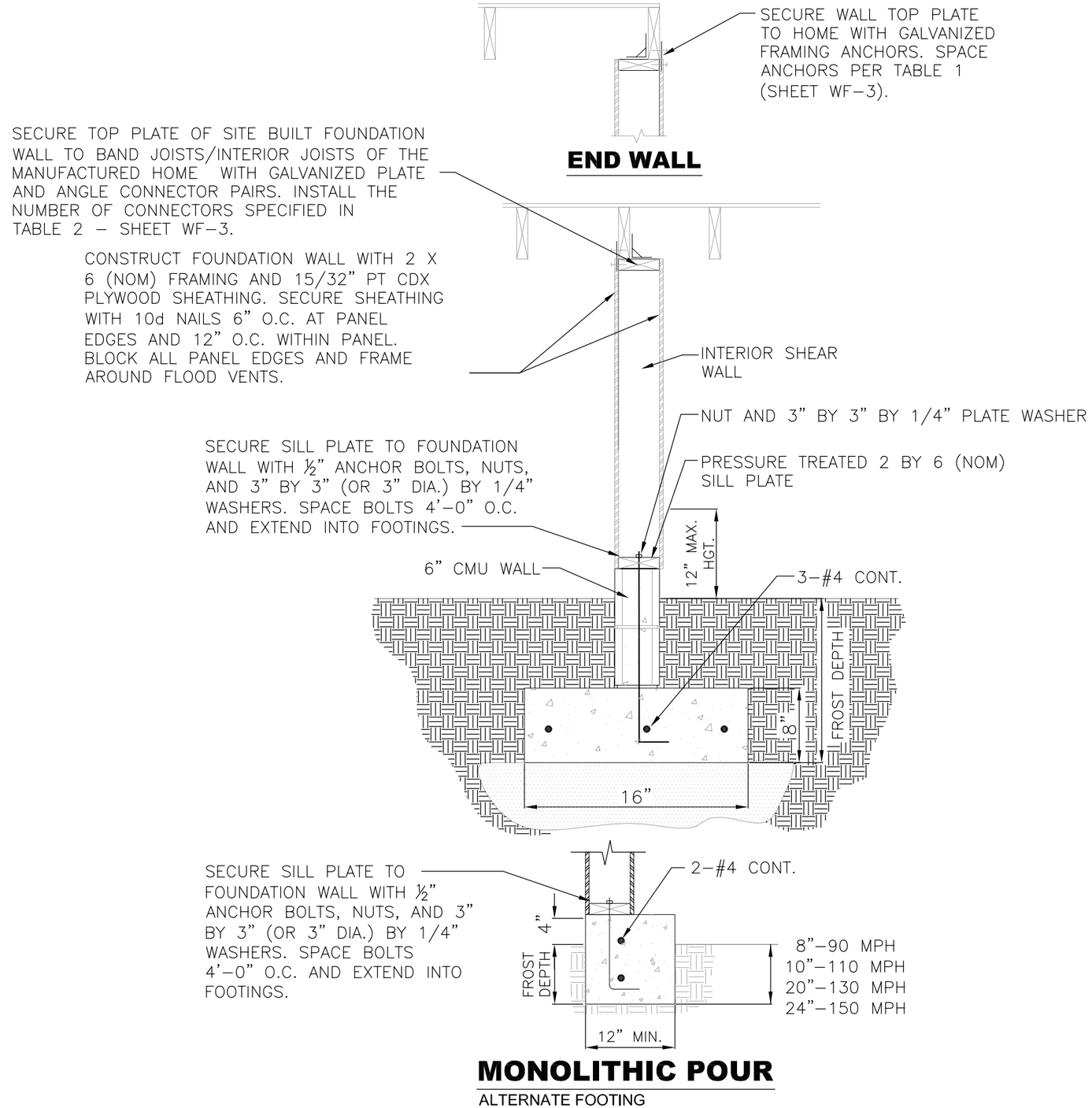
[4]Consult with home manufacturer to verify the home framing is adequate to transfer specified loads at the connection points indicated.

WF1

WOOD FRAMED FOUNDATION DETAIL

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


SECURE WALL TOP PLATE TO HOME WITH GALVANIZED FRAMING ANCHORS. SPACE ANCHORS PER TABLE 1 (SHEET WF–3).
END WALL
SECURE TOP PLATE OF SITE BUILT FOUNDATION WALL TO BAND JOISTS/INTERIOR JOISTS OF THE MANUFACTURED HOME WITH GALVANIZED PLATE AND ANGLE CONNECTOR PAIRS. INSTALL THE NUMBER OF CONNECTORS SPECIFIED IN TABLE 2 – SHEET WF–3.
CONSTRUCT FOUNDATION WALL WITH 2 X 6 (NOM) FRAMING AND 15/32" PT CDX PLYWOOD SHEATHING. SECURE SHEATHING WITH 10d NAILS 6" O.C. AT PANEL EDGES AND 12" O.C. WITHIN PANEL. BLOCK ALL PANEL EDGES AND FRAME AROUND FLOOD VENTS.
INTERIOR SHEAR WALL
NUT AND 3" BY 3" BY 1/4" PLATE WASHER
PRESSURE TREATED 2 BY 6 (NOM) SILL PLATE
SECURE SILL PLATE TO FOUNDATION WALL WITH ½" ANCHOR BOLTS, NUTS, AND 3" BY 3" (OR 3" DIA.) BY 1/4" WASHERS. SPACE BOLTS 4'–0" O.C. AND EXTEND INTO FOOTINGS.
6" CMU WALL
12" MAX. HGT.
3–#4 CONT.
FROST DEPTH
8"
16"
SECURE SILL PLATE TO FOUNDATION WALL WITH ½" ANCHOR BOLTS, NUTS, AND 3" BY 3" (OR 3" DIA.) BY 1/4" WASHERS. SPACE BOLTS 4'–0" O.C. AND EXTEND INTO FOOTINGS.
2–#4 CONT.
4"
FROST DEPTH
8"–90 MPH
10"–110 MPH
20"–130 MPH
24"–150 MPH
12" MIN.

MONOLITHIC POUR

ALTERNATE FOOTING

WF2

WOOD FRAMED SHEAR WALL DETAIL

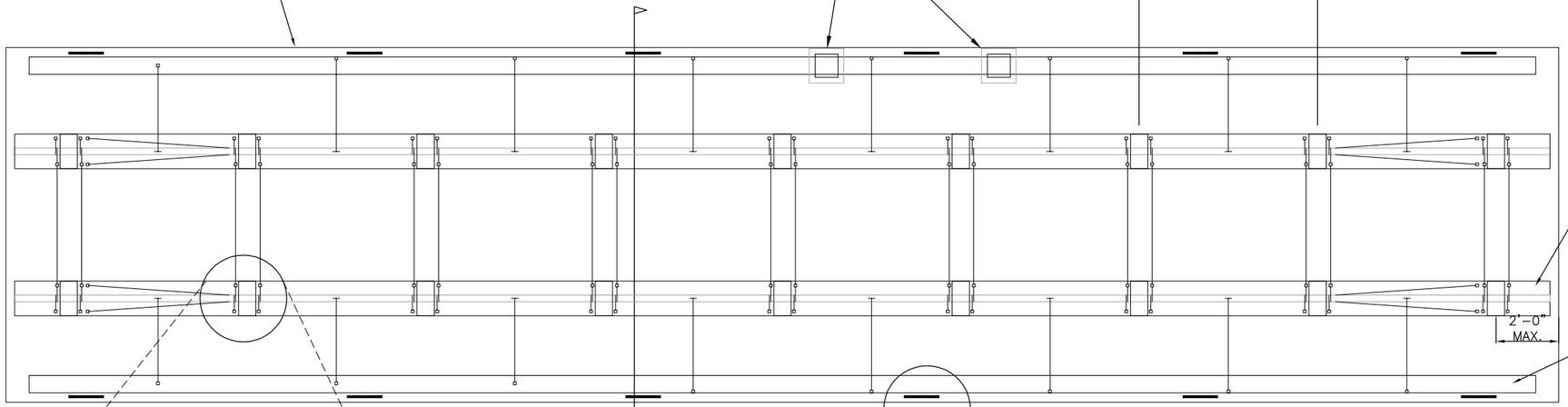
NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.

NON–STRUCTURAL SKIRTING

PIER SPACING SEE TABLE THIS SHEET

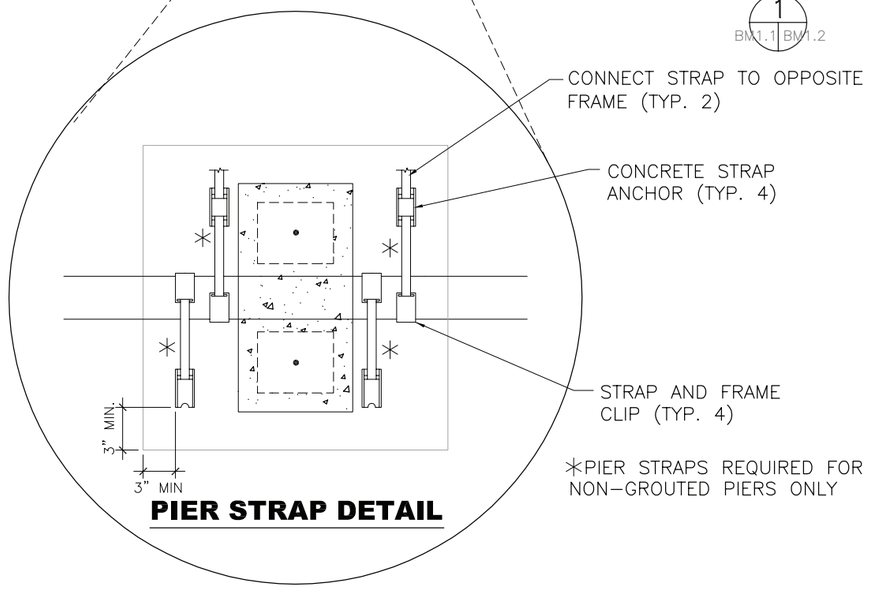


CONTINUOUS CONCRETE FRAME FOOTINGS UNDER FRAMES (TYP. 2)

2'–0" MAX.

CONTINUOUS CONCRETE PERIMETER FOOTING – 110, 130, AND 150 MPH DESIGNS ONLY (TYP. 2)

1
BM1.1 BM1.2


CONNECT STRAP TO OPPOSITE FRAME (TYP. 2)
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN
✳PIER STRAPS REQUIRED FOR NON–GROUTED PIERS ONLY

PIER STRAP DETAIL

FLOOD AND CRAWLSPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

Braced Masonry Pier Foundation - Pier, Footing and Tie Schedule (Minimum 1,000 lb/ft^2 Soil Bearing Capacity Required)

Wind Speed	Frame Footing (W by D)	Perimeter Footing (W by D)	Pier Spacing[1]	Wall Tie Spacing[2,3]	Frame Tie Spacing[2,3]
Single Unit					
90 mph	16" by 10"	Not Required	10'-0"	Not Required	8'-0"
110 mph	16" by 12"	8" by 16"	10'-0"	10'-8"	5'-4"
130 mph	16" by 12"	12" by 16"	8'-0"	8'-0"	4'-0"
150 mph	16" by 12"	12" by 24"	8'-0"	5'-4"	2'-8"

[1] Locate end piers within 2'-0" of the ends of the home.
[2] Wall and frame ties may be connected to a single concrete anchor.
[3] Install wall and frame straps in other locations if required by the manufacturer.

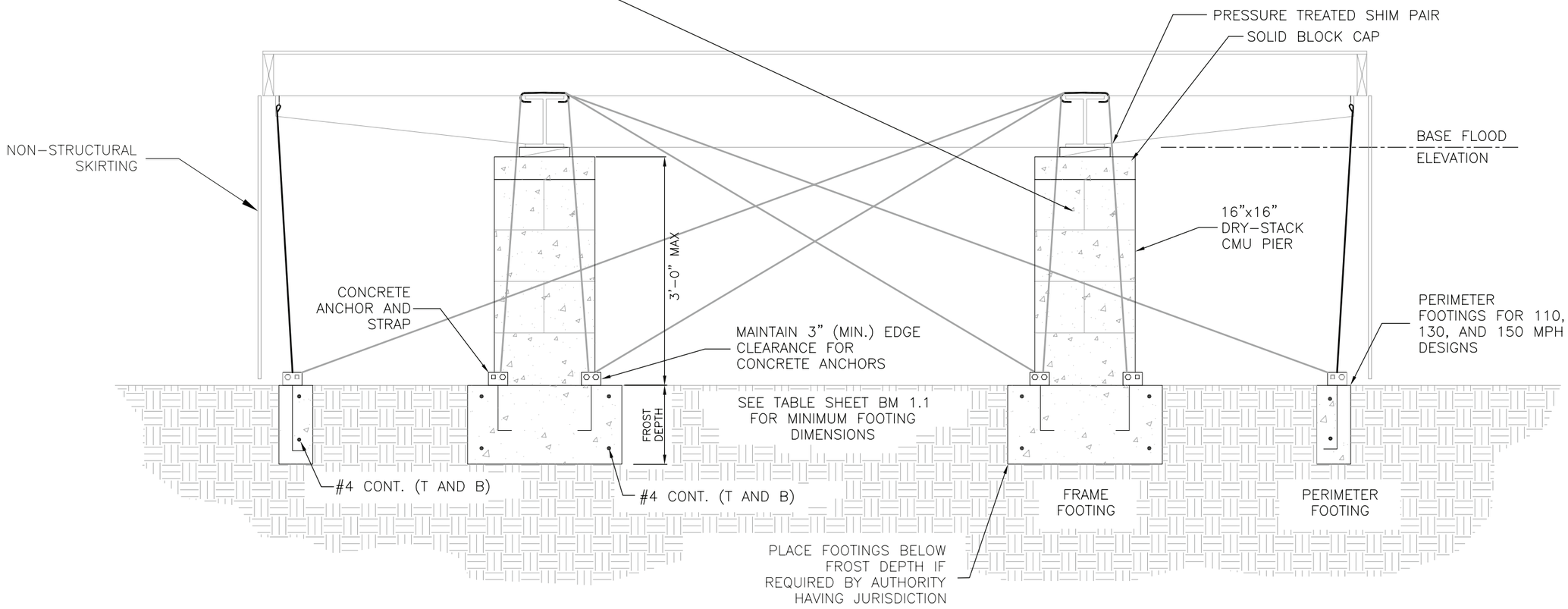
SINGLE UNIT BRACED MASONRY PIER FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

16" BY 16" MASONRY PIER AND CAST-IN-PLACE FOOTING:
SECURE PIER, FOOTING AND FRAME WITH STRAPS, FRAME CLIPS, AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOOTINGS SHALL BE CONTINUOUS CAST-IN-PLACE CONCRETE. PROVIDE FOOTINGS UNDER HOUSE FRAMES FOR ALL WIND ZONES UNDER PERIMETER WALLS FOR 110, 130, AND 150 MPH WIND ZONES. CONTINUE ALL FOOTINGS TO APPROXIMATELY 6" FROM THE ENDS OF THE HOME. SEE BRACED MASONRY PIER FOUNDATION – PIER, FOOTING, AND TIE SCHEDULE FOR PIER SPACING AND FOOTING DIMENSIONS.

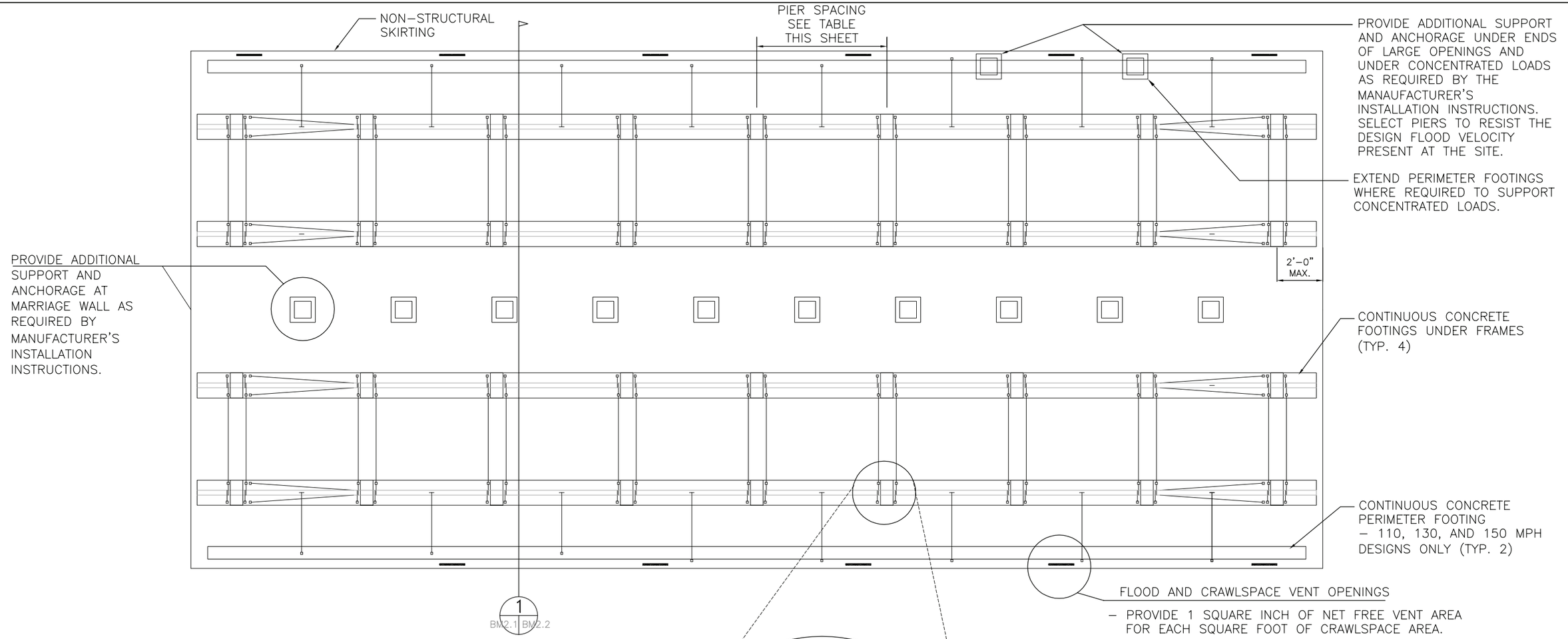

PRESSURE TREATED SHIM PAIR
SOLID BLOCK CAP
NON-STRUCTURAL SKIRTING
BASE FLOOD ELEVATION
16"x16" DRY-STACK CMU PIER
3'-0" MAX
CONCRETE ANCHOR AND STRAP
MAINTAIN 3" (MIN.) EDGE CLEARANCE FOR CONCRETE ANCHORS
PERIMETER FOOTINGS FOR 110, 130, AND 150 MPH DESIGNS
FROST DEPTH
SEE TABLE SHEET BM 1.1 FOR MINIMUM FOOTING DIMENSIONS
#4 CONT. (T AND B)
#4 CONT. (T AND B)
FRAME FOOTING
PERIMETER FOOTING
PLACE FOOTINGS BELOW FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION

1
BM1.1 | BM1.2

BRACED MASONRY PIER DETAIL

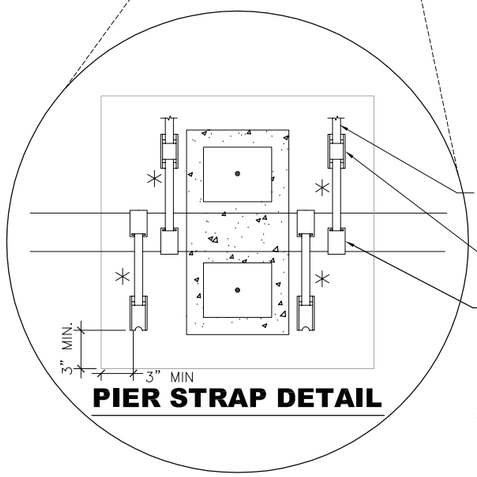
NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1


NON–STRUCTURAL SKIRTING
PIER SPACING SEE TABLE THIS SHEET
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANAUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
EXTEND PERIMETER FOOTINGS WHERE REQUIRED TO SUPPORT CONCENTRATED LOADS.
2'–0" MAX.
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL AS REQUIRED BY MANUFACTURER'S INSTALLATION INSTRUCTIONS.
CONTINUOUS CONCRETE FOOTINGS UNDER FRAMES (TYP. 4)
CONTINUOUS CONCRETE PERIMETER FOOTING – 110, 130, AND 150 MPH DESIGNS ONLY (TYP. 2)
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
1
BM2.1 BM2.2

Braced Masonry Pier Foundation - Pier, Footing and Tie Schedule (Minimum 1,000 lb/ft^2 Soil Bearing Capacity Required)					
Wind Speed	**Frame Footing (W by D)**	**Perimeter Footing (W by D)**	**Pier Spacing[1]**	**Wall Tie Spacing[2,3]**	**Frame Tie Spacing[2,3]**
Double Unit					
90 mph	16" by 12"	Not Required	10'-0"	Not Required	8'-0"
110 mph	16" by 12"	8" by 16"	10'-0"	6'-8"	3'-4"
130 mph	16" by 12"	12" by 16"	8'-0"	6'-8"	3'-4"
150 mph	16" by 12"	12" by 24"	8'-0"	5'-4"	2'-8"

[1] Locate end piers within 2'0" of the ends of the home.
[2] Wall and frame ties may be connected to a single concrete anchor.
[3] Install wall and frame straps in other locations if required by the manufacturer.



PIER STRAP DETAIL

CONNECT STRAP TO OPPOSITE FRAME (TYP. 2)
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)

✳PIER STRAPS REQUIRED FOR NON–GROUTED PIERS ONLY

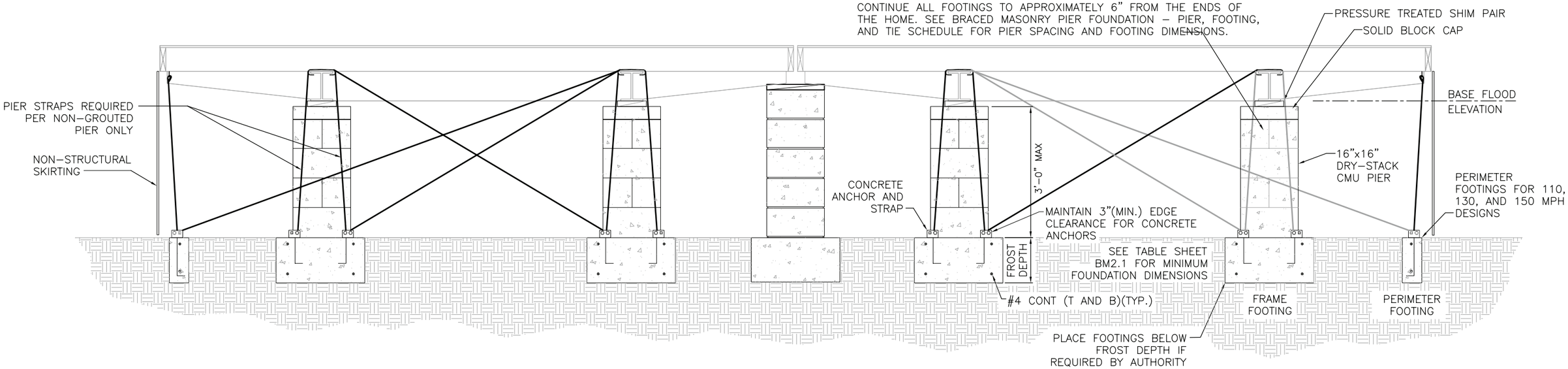
DOUBLE UNIT BRACED MASONRY PIER FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

16" BY 16" MASONRY PIER AND CAST–IN–PLACE FOOTING:
SECURE PIER, FOOTING, AND FRAME WITH STRAPS, FRAME CLIPS, AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

FOOTINGS SHALL BE CONTINUOUS CAST–IN–PLACE CONCRETE. PROVIDE FOOTINGS UNDER HOUSE FRAMES FOR ALL WIND ZONES UNDER PERIMETER WALLS FOR 110, 130, AND 150 MPH WIND ZONES. CONTINUE ALL FOOTINGS TO APPROXIMATELY 6" FROM THE ENDS OF THE HOME. SEE BRACED MASONRY PIER FOUNDATION – PIER, FOOTING, AND TIE SCHEDULE FOR PIER SPACING AND FOOTING DIMENSIONS.

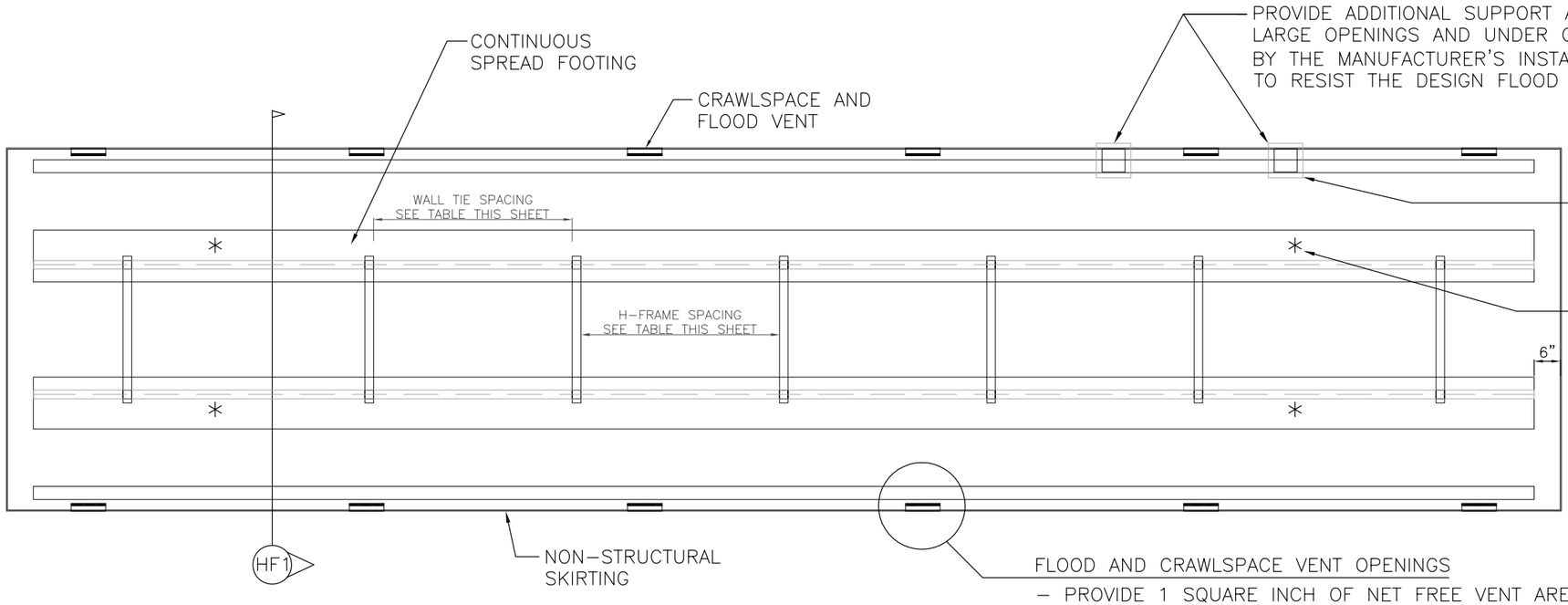

PRESSURE TREATED SHIM PAIR
SOLID BLOCK CAP
BASE FLOOD ELEVATION
PIER STRAPS REQUIRED PER NON–GROUTED PIER ONLY
NON–STRUCTURAL SKIRTING
16"x16" DRY–STACK CMU PIER
PERIMETER FOOTINGS FOR 110, 130, AND 150 MPH DESIGNS
CONCRETE ANCHOR AND STRAP
3'–0" MAX
MAINTAIN 3"(MIN.) EDGE CLEARANCE FOR CONCRETE ANCHORS
FROST DEPTH
SEE TABLE SHEET BM2.1 FOR MINIMUM FOUNDATION DIMENSIONS
#4 CONT (T AND B)(TYP.)
FRAME FOOTING
PERIMETER FOOTING
PLACE FOOTINGS BELOW FROST DEPTH IF REQUIRED BY AUTHORITY HAVING JURISDICTION

1
BM2.1 BM2.2

BRACED MASONRY PIER DETAIL

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


CONTINUOUS
SPREAD FOOTING
CRAWLSPACE AND
FLOOD VENT
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
WALL TIE SPACING
SEE TABLE THIS SHEET
H–FRAME SPACING
SEE TABLE THIS SHEET
EXTEND PERIMETER FOOTINGS WHERE REQUIRED TO SUPPORT CONCENTRATED LOADS.
*PROVIDE 2x6 LONGITUDINAL CROSS BRACING BETWEEN H–FRAME POSTS. ALTERNATE ORIENTATION FOR ADJACENT BRACES.
6"
HF1
NON–STRUCTURAL
SKIRTING

FLOOD AND CRAWLSPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

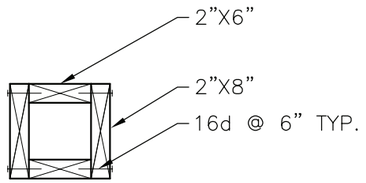
H–FRAME SPACING TABLE

WIND SPEED	H–FRAME SPACING	WALL TIE SPACING	FRAME FOOTING (WxD)	PERIMETER FOOTING (WxD)
90 mph	8'–0"	–	16"X8"	–
110 mph	6'–8"	6'–8"	16"X8"	12"X12"
130 mph	5'–4"	5'–4"	16"X12"	12"X16"
150 mph	4'–0"	4'–0"	20"X12"	12"X18"

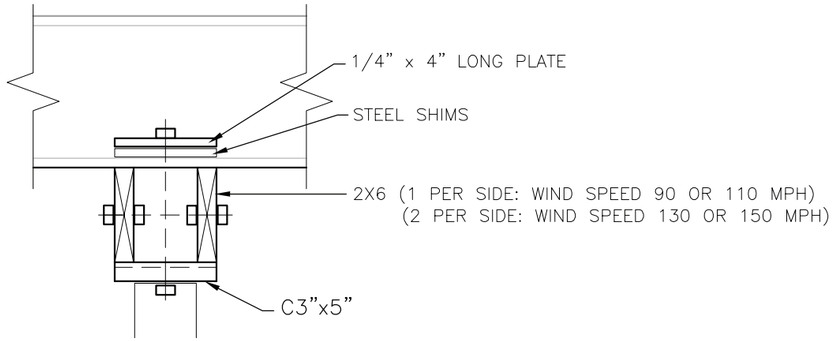
SINGLE UNIT BRACED WOOD H-FRAME FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

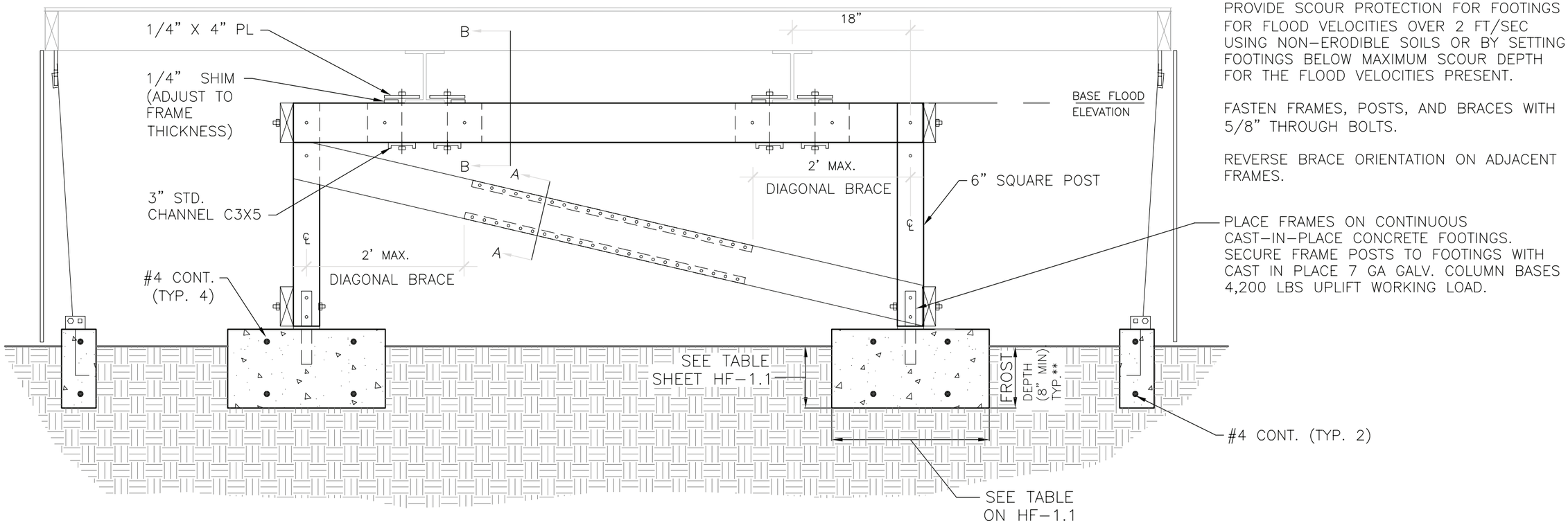
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1



SECTION A–A



SECTION B–B


1/4" X 4" PL
1/4" SHIM (ADJUST TO FRAME THICKNESS)
3" STD. CHANNEL C3X5
#4 CONT. (TYP. 4)
B
A
2' MAX. DIAGONAL BRACE
18"
BASE FLOOD ELEVATION
6" SQUARE POST
PLACE FRAMES ON CONTINUOUS CAST–IN–PLACE CONCRETE FOOTINGS. SECURE FRAME POSTS TO FOOTINGS WITH CAST IN PLACE 7 GA GALV. COLUMN BASES 4,200 LBS UPLIFT WORKING LOAD.
SEE TABLE SHEET HF–1.1
FROST DEPTH (8" MIN) TYP.**
#4 CONT. (TYP. 2)
SEE TABLE ON HF–1.1

PLACE FOOTINGS AT OR BELOW FROST DEPTH AS DETERMINED BY BY AUTHORITY HAVING JURISDICTION.

PROVIDE SCOUR PROTECTION FOR FOOTINGS FOR FLOOD VELOCITIES OVER 2 FT/SEC USING NON–ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

FASTEN FRAMES, POSTS, AND BRACES WITH 5/8" THROUGH BOLTS.

REVERSE BRACE ORIENTATION ON ADJACENT FRAMES.

* ON HOMES WHERE PERIMETER FOOTINGS ARE WITHIN 1 FOOT OF FRAME FOOTING, COMBINE FRAME FOOTING WITH PERIMETER FOOTING. SIZE OF COMBINED FOOTING MUST BE EQUAL OR GREATER THAN SUM OF INDIVIDUAL FOOTINGS AREAS.

**INCREASE FOOTING DEPTHS AS REQUIRED TO PLACE BOTTOM OF FOOTING BELOW DESIGN FROST DEPTH AS DETERMINED BY LOCAL BUILDING OFFICIAL. FOOTING MAY BE REDUCED PROPORTIONALLY PROVIDED:
(1) CROSS–SECTION AREA OF FOOTING IS NOT REDUCED AND
(2) A MINIMUM WIDTH OF 16" IS MAINTAINED

HF1

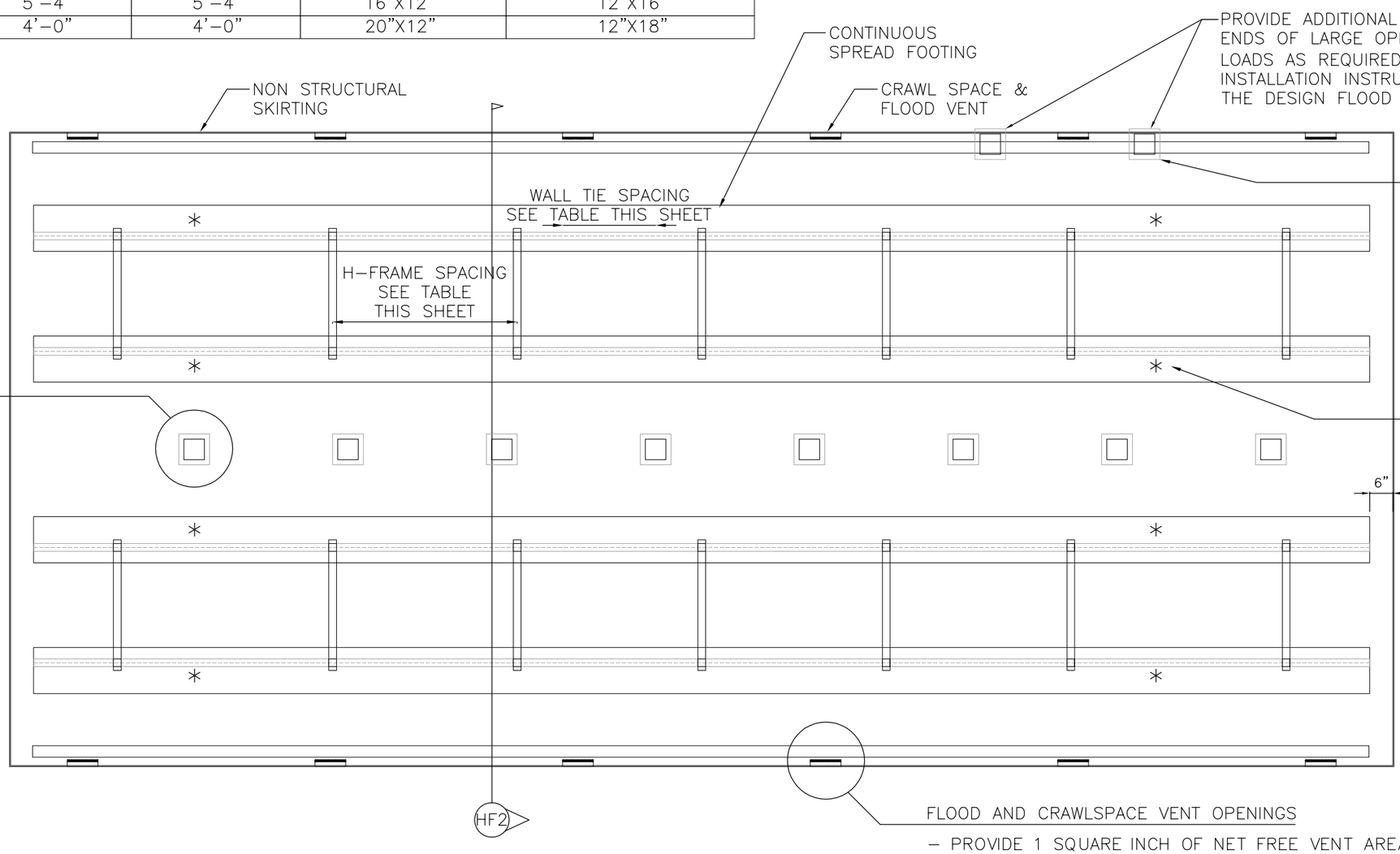
SINGLE UNIT WOOD H-FRAME DETAIL

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

H–FRAME SPACING TABLE

WIND SPEED	H–FRAME SPACING	WALL TIE SPACING	FRAME FOOTING (WxD)	PERIMETER FOOTING (WxD)
90 mph	8'–0"	–	16"X8"	–
110 mph	6'–8"	6'–8"	16"X8"	12"X12"
130 mph	5'–4"	5'–4"	16"X12"	12"X16"
150 mph	4'–0"	4'–0"	20"X12"	12"X18"

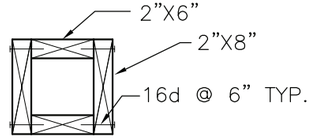

NON STRUCTURAL SKIRTING
CONTINUOUS SPREAD FOOTING
CRAWL SPACE & FLOOD VENT
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
EXTEND PERIMETER FOOTINGS WHERE REQUIRED TO SUPPORT CONCENTRATED LOADS.
WALL TIE SPACING SEE TABLE THIS SHEET
H–FRAME SPACING SEE TABLE THIS SHEET
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL AS REQUIRED BY MANUFACTURER'S INSTALLATION INSTRUCTIONS.
*PROVIDE 2x6 LONGITUDINAL CROSS BRACING BETWEEN H–FRAME POSTS. ALTERNATE ORIENTATION FOR ADJACENT BRACES.
6"
HF2
FLOOD AND CRAWLSPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA PER SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

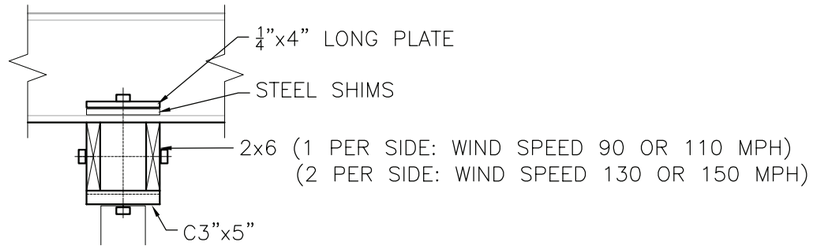
DOUBLE UNIT BRACED WOOD H-FRAME FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

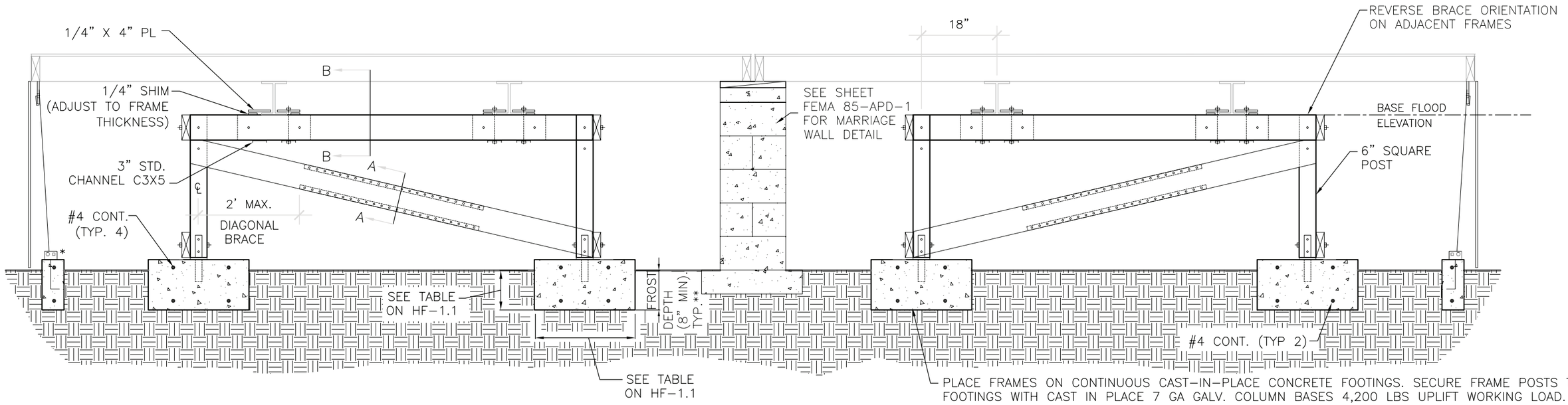
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1



SECTION A–A



SECTION B–B



* ON HOMES WHERE PERIMETER FOOTINGS ARE WITHIN 1 FOOT OF FRAME FOOTING, COMBINE FRAME FOOTING WITH PERIMETER FOOTING. SIZE OF COMBINED FOOTING MUST BE EQUAL OR GREATER THAN SUM OF INDIVIDUAL FOOTINGS AREAS.

**INCREASE FOOTING DEPTHS AS DETERMINED BY LOCAL BUILDING OFFICIAL TO PLACE BOTTOM OF FOOTING BELOW DESIGN FROST DEPTH. FOOTING MAY BE REDUCED PROPORTIONALLY PROVIDED:
(1) CROSS–SECTION AREA OF FOOTING IS NOT REDUCED AND
(2) A MINIMUM WIDTH OF 16" IS MAINTAINED

PLACE FRAMES ON CONTINUOUS CAST–IN–PLACE CONCRETE FOOTINGS. SECURE FRAME POSTS TO FOOTINGS WITH CAST IN PLACE 7 GA GALV. COLUMN BASES 4,200 LBS UPLIFT WORKING LOAD.

PLACE FOOTINGS AT FROST DEPTH AS DETERMINED BY LOCAL BUILDING OFFICIAL.

PROVIDE SCOUR PROTECTION FOR FOOTINGS FOR FLOOD VELOCITIES OVER 2 FT/SEC USING NON–ERODIBLE SOILS OR BY SETTING FOOTINGS BELOW MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.

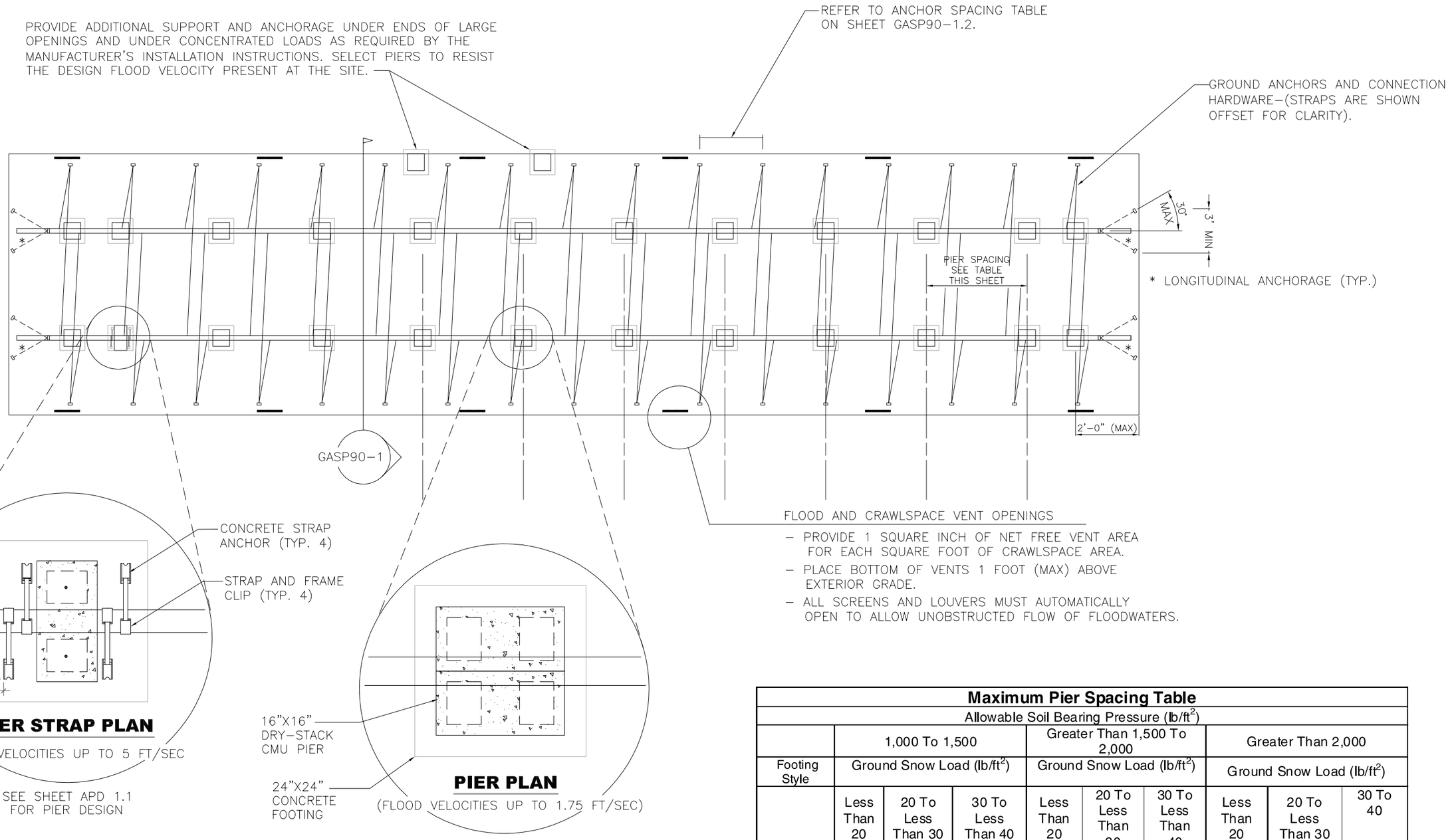
FASTEN FRAMES, POSTS, AND BRACES WITH 5/8" THROUGH BOLTS.

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA, AND LIMITATIONS. SHEET GN–1.1

HF2

DOUBLE UNIT WOOD H-FRAME DETAIL

NOT TO SCALE


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
REFER TO ANCHOR SPACING TABLE ON SHEET GASP90-1.2.
GROUND ANCHORS AND CONNECTION HARDWARE-(STRAPS ARE SHOWN OFFSET FOR CLARITY).
30° MAX
3" MIN
* LONGITUDINAL ANCHORAGE (TYP.)
PIER SPACING SEE TABLE THIS SHEET
2'-0" (MAX)
GASP90-1
FLOOD AND CRAWLSPACE VENT OPENINGS
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
PIER STRAP PLAN
FLOOD VELOCITIES UP TO 5 FT/SEC
SEE SHEET APD 1.1 FOR PIER DESIGN
16"X16" DRY-STACK CMU PIER
24"X24" CONCRETE FOOTING
PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft^2)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-3"	4'-9"	4'-2"	7'-10"	7'-2"	6'-6"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

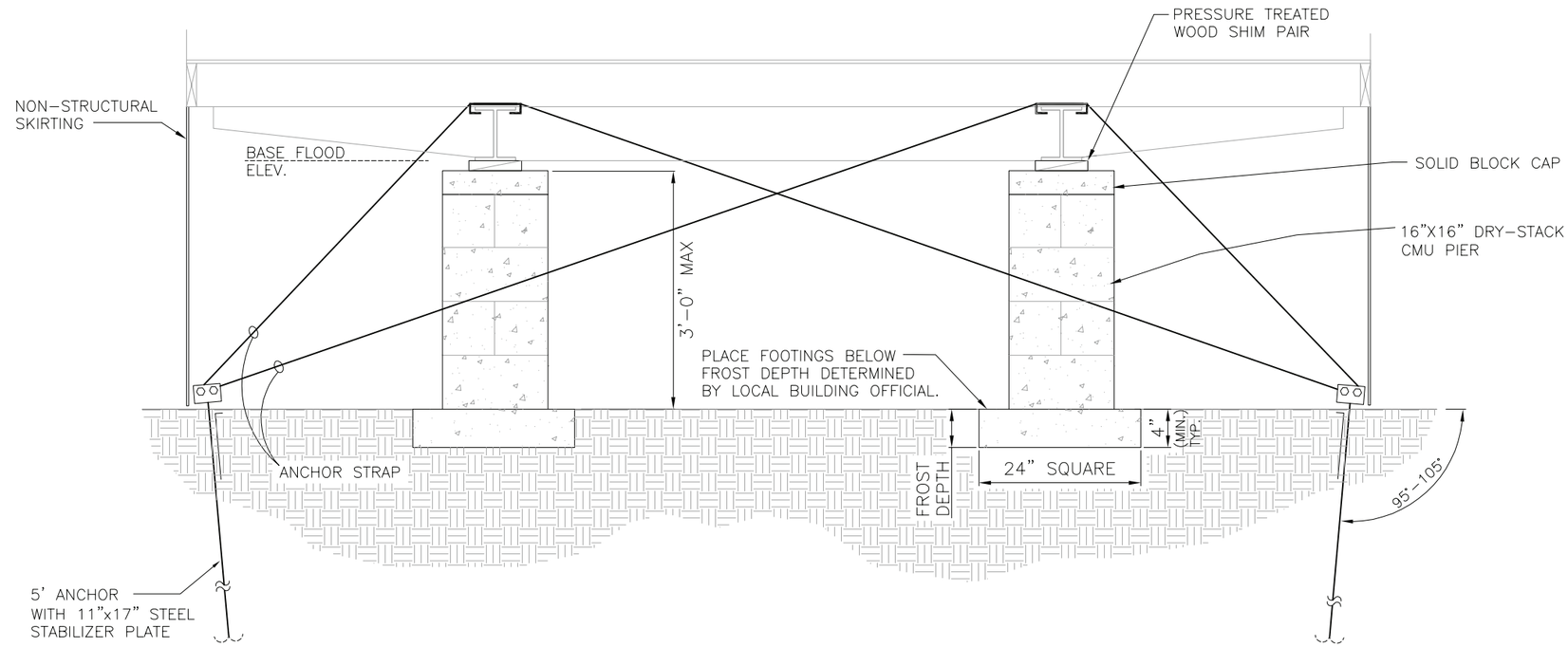
SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 1,500 LBS

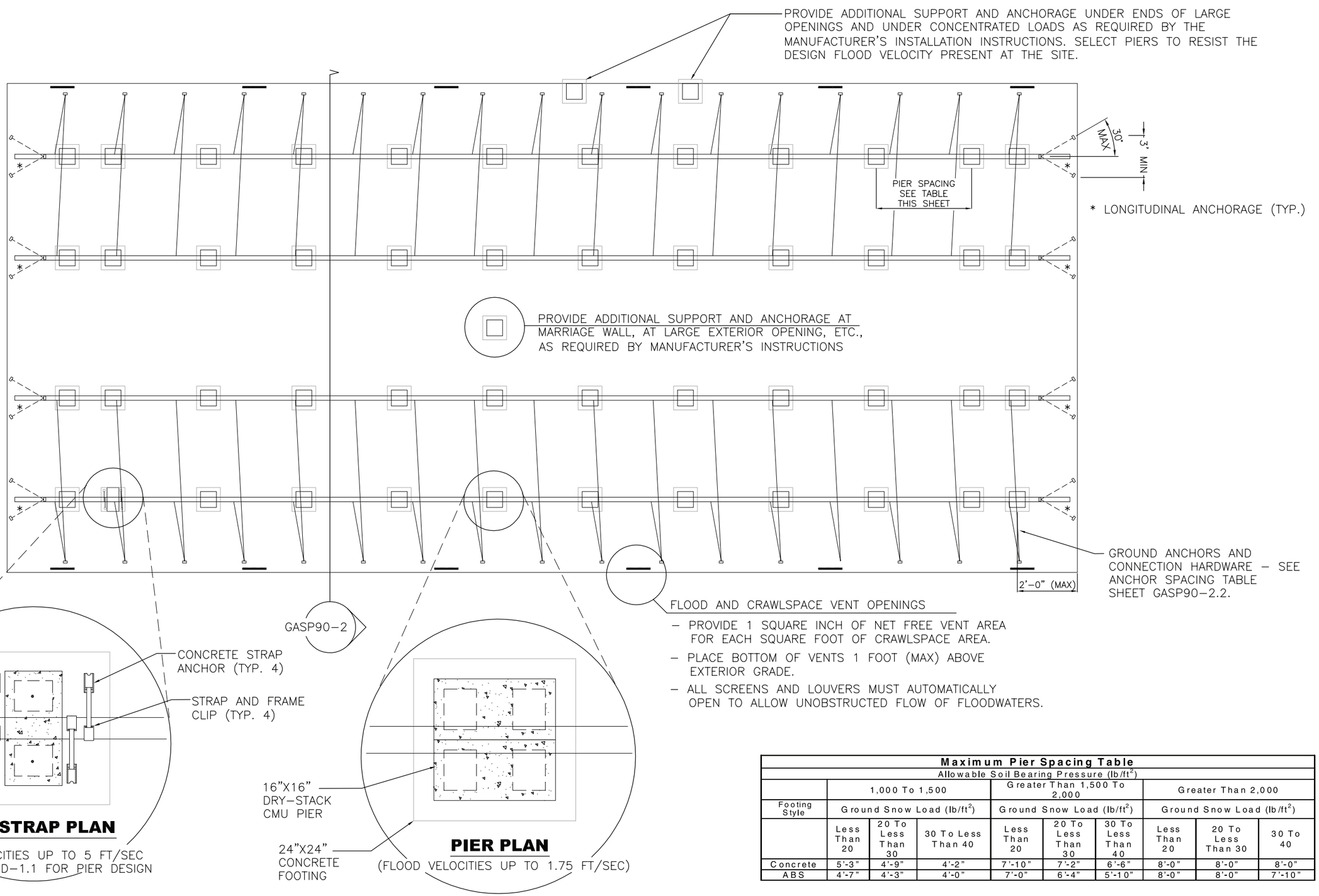


GASP90–1

GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
30° MAX
3' MIN
PIER SPACING SEE TABLE THIS SHEET
* LONGITUDINAL ANCHORAGE (TYP.)
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL, AT LARGE EXTERIOR OPENING, ETC., AS REQUIRED BY MANUFACTURER'S INSTRUCTIONS
GASP90-2
GROUND ANCHORS AND CONNECTION HARDWARE – SEE ANCHOR SPACING TABLE SHEET GASP90-2.2.
2'-0" (MAX)
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
PIER STRAP PLAN
FLOOD VELOCITIES UP TO 5 FT/SEC
SEE SHEET APD–1.1 FOR PIER DESIGN
16"X16" DRY–STACK CMU PIER
24"X24" CONCRETE FOOTING
PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table									
Allowable Soil Bearing Pressure (lb/ft²)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)		
	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-3"	4'-9"	4'-2"	7'-10"	7'-2"	6'-6"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

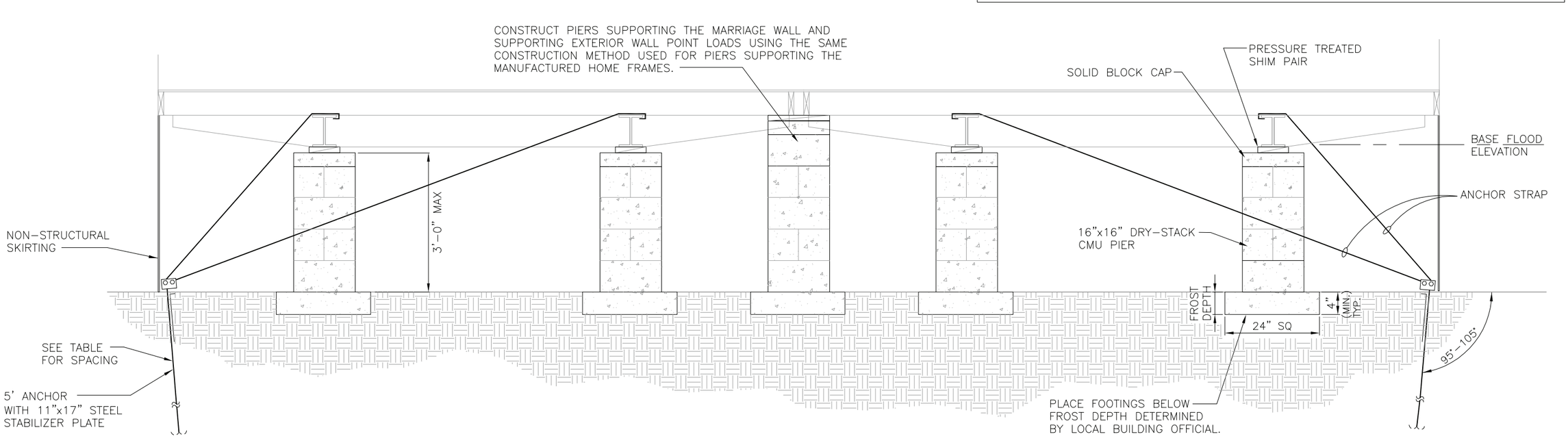
DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 1,500 LBS


CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.
PRESSURE TREATED SHIM PAIR
SOLID BLOCK CAP
BASE FLOOD ELEVATION
ANCHOR STRAP
NON–STRUCTURAL SKIRTING
3'–0" MAX
16"x16" DRY–STACK CMU PIER
FROST DEPTH
4" (MIN.) TYP.
24" SQ
95°–105°
SEE TABLE FOR SPACING
5' ANCHOR WITH 11"x17" STEEL STABILIZER PLATE
PLACE FOOTINGS BELOW FROST DEPTH DETERMINED BY LOCAL BUILDING OFFICIAL.

GASP90–2

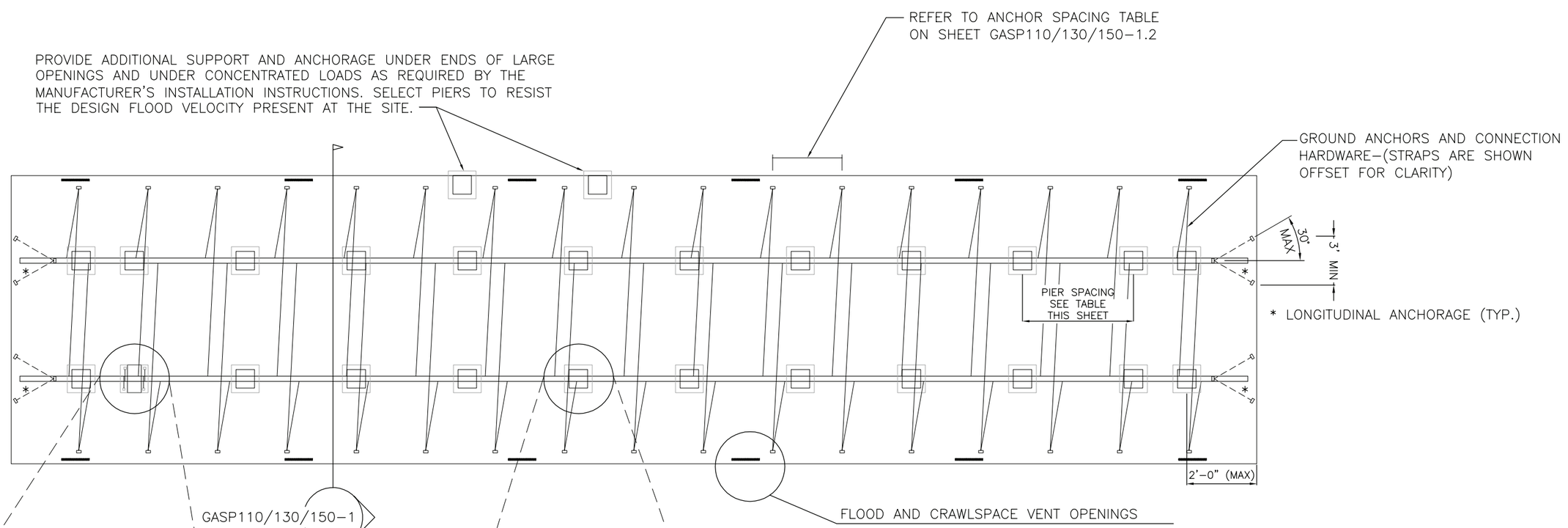
GROUND ANCHOR AND PIER DETAIL (DOUBLE UNIT)

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

Sept 2009

FEMA 85 GASP90-2.2


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
REFER TO ANCHOR SPACING TABLE ON SHEET GASP110/130/150-1.2
GROUND ANCHORS AND CONNECTION HARDWARE-(STRAPS ARE SHOWN OFFSET FOR CLARITY)
30° MAX
3" MIN
PIER SPACING SEE TABLE THIS SHEET
* LONGITUDINAL ANCHORAGE (TYP.)
2'-0" (MAX)
GASP110/130/150-1
FLOOD AND CRAWLSPACE VENT OPENINGS
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
PIER STRAP PLAN
FLOOD VELOCITIES UP TO 5 FT/SEC
SEE SHEET APD-1.1 FOR PIER DESIGN
16"X16" DRY-STACK CMU PIER
24"X24" CONCRETE FOOTING
PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft^2)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-1"	4'-7"	4'-2"	7'-7"	6'-10"	6'-4"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

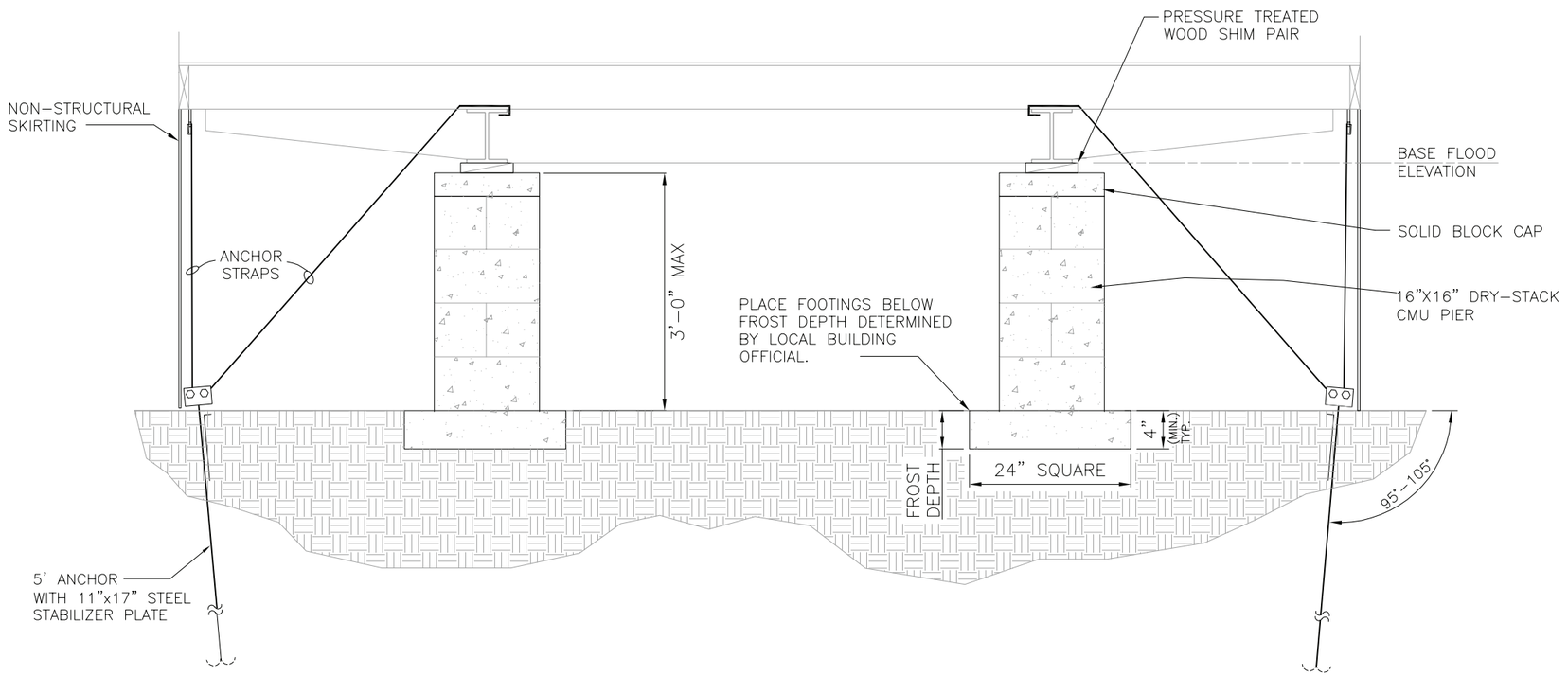
SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 1,500 LBS

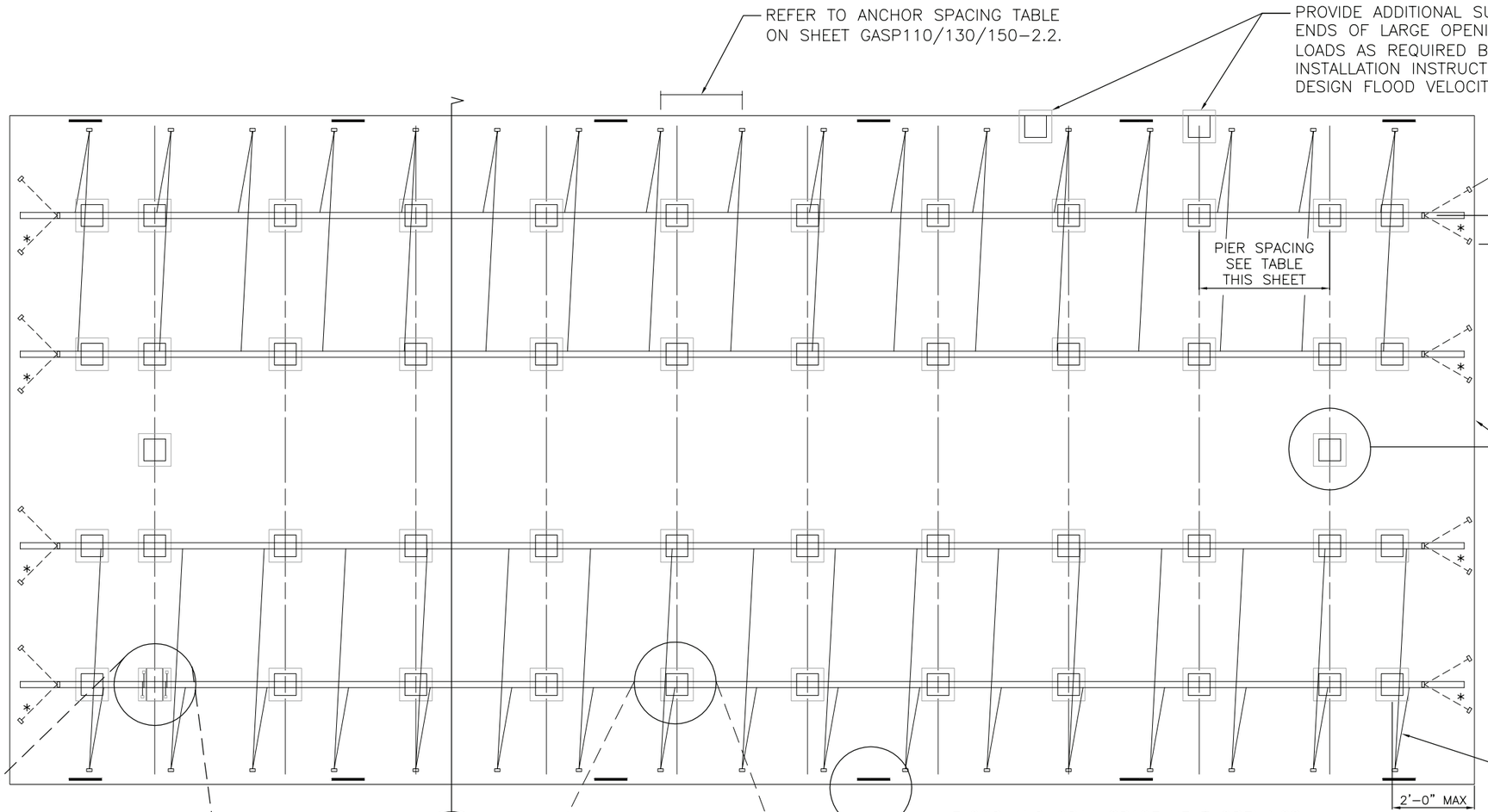


GASP110/130/150–1

GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


REFER TO ANCHOR SPACING TABLE ON SHEET GASP110/130/150–2.2.
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
30° MAX
3' MIN
PIER SPACING SEE TABLE THIS SHEET
* LONGITUDINAL ANCHORAGE (TYP.)
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL, AT LARGE EXTERIOR OPENING, ETC. AS REQUIRED BY MANUFACTURER'S INSTRUCTIONS.
GROUND ANCHORS AND CONNECTION HARDWARE
–SEE ANCHOR SPACING TABLE (SHEET GASP 110/130/150–2.2).
2'–0" MAX
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
GASP110/130/150–1
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN
PIER STRAP PLAN
(FLOOD VELOCITIES UP TO 5 FT/SEC)
SEE SHEET APD–1.1 FOR PIER DESIGN
16"X16" DRY–STACK CMU PIER
24"X24" CONCRETE FOOTING
PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft²)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-1"	4'-7"	4'-2"	7'-7"	6'-10"	6'-4"	8'-0"	8'-0"	8'-0"
ABS	4'-4"	4'-0"	3'-6"	6'-6"	6'-0"	5'-6"	8'-0"	7'-6"	7'-0"

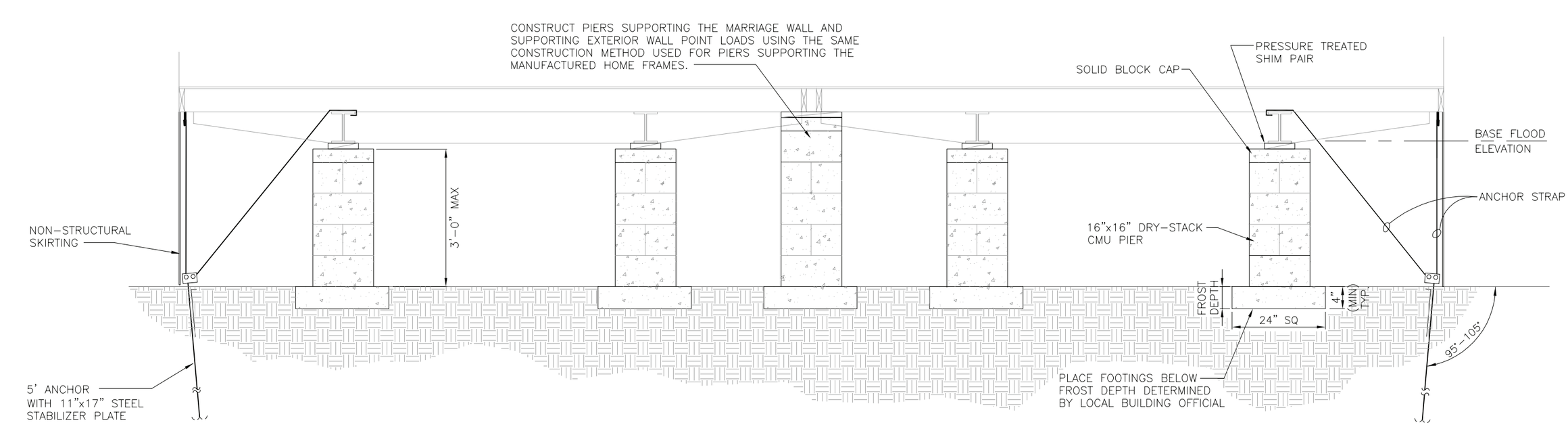
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE - CONTINUOUS SPREAD FOOTING

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 1,500 LBS


CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.
SOLID BLOCK CAP
PRESSURE TREATED SHIM PAIR
BASE FLOOD ELEVATION
ANCHOR STRAP
NON–STRUCTURAL SKIRTING
3'–0" MAX
16"x16" DRY–STACK CMU PIER
FROST DEPTH
4" (MIN) TYP.
24" SQ
95°–105°
5' ANCHOR WITH 11"x17" STEEL STABILIZER PLATE
PLACE FOOTINGS BELOW FROST DEPTH DETERMINED BY LOCAL BUILDING OFFICIAL

GASP110/130/150–1

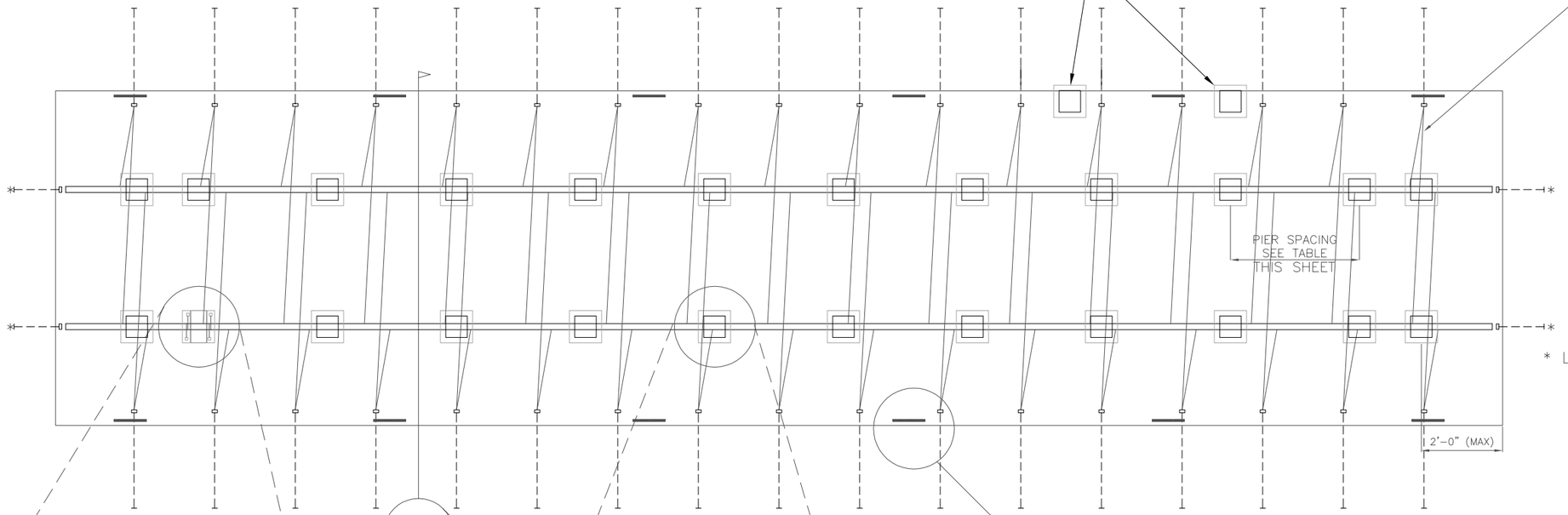
GROUND ANCHOR AND PIER DETAIL (DOUBLE UNIT)

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

SEE ALTERNATIVE PIER DETAILS FOR VELOCITIES GREATER THAN 1.75 FPS. SHEET APD 1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

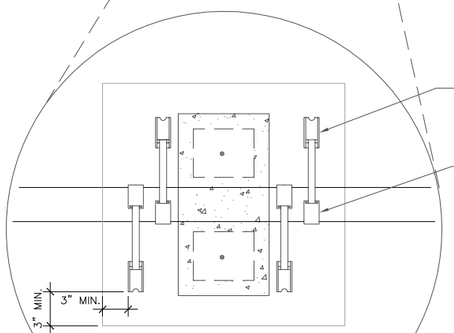
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.

GROUND ANCHORS AND CONNECTION HARDWARE–(STRAPS ARE SHOWN OFFSET FOR CLARITY)



FLOOD AND CRAWLSPACE VENT OPENINGS

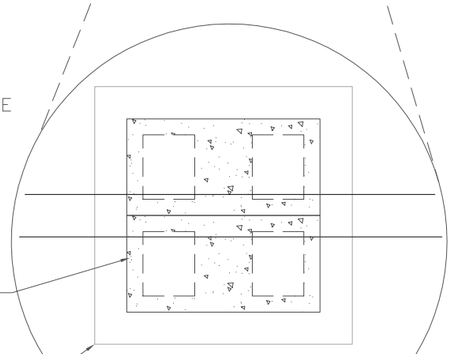
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.



PIER STRAP PLAN

FLOOD VELOCITIES UP TO 5 FT/SEC

SEE SHEET APD–1.1 FOR PIER DESIGN



PIER PLAN

(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft^2)

Footing Style	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To Less Than 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-3"	4'-9"	4'-2"	7'-10"	7'-2"	6'-6"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

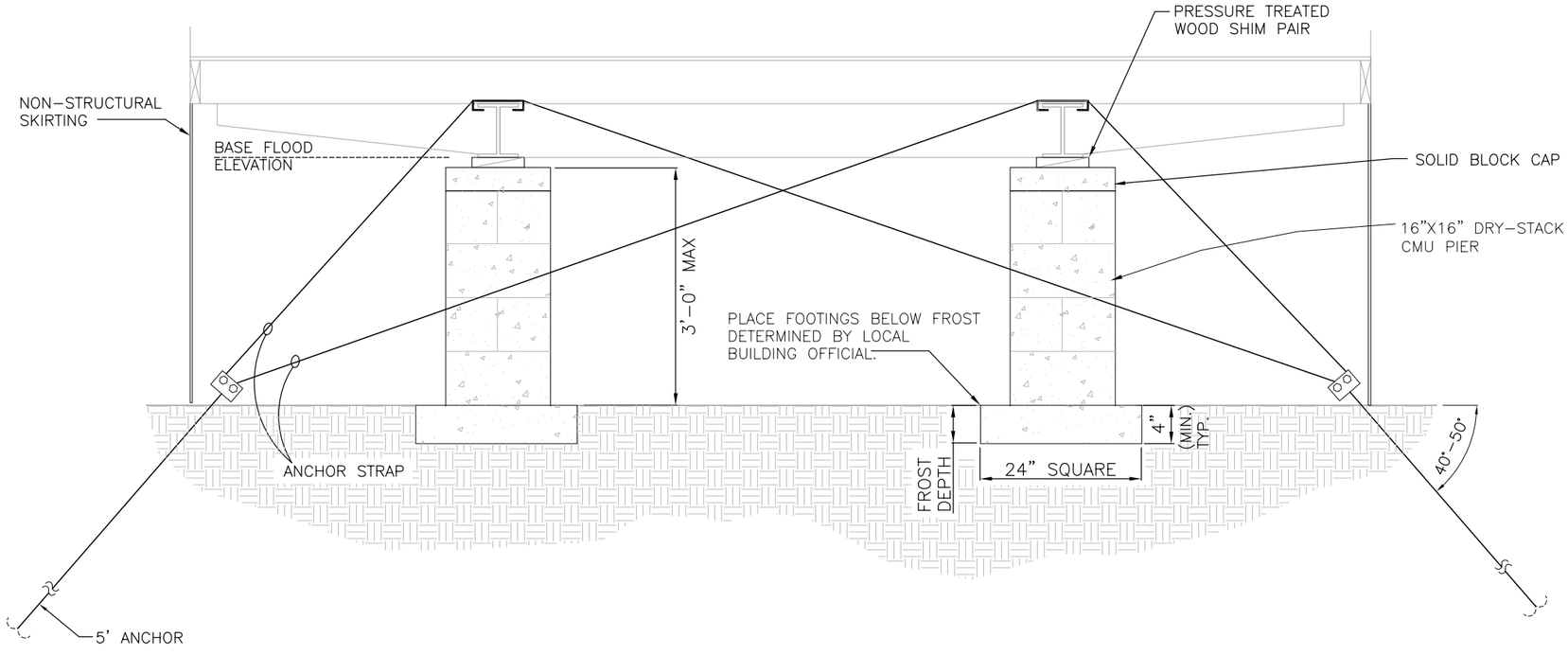
SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 3,150 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS

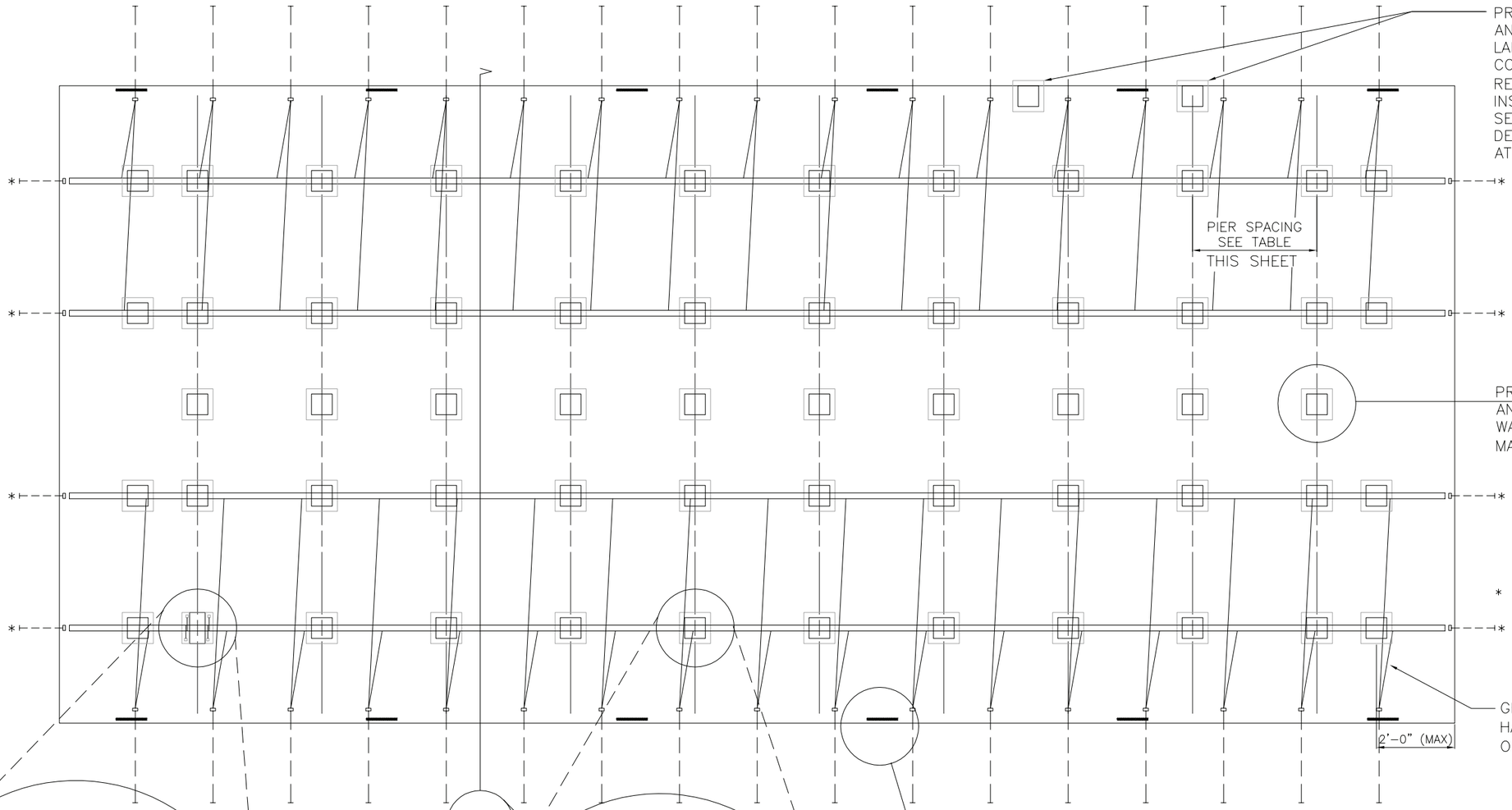


GA90–1

GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD 1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
PIER SPACING SEE TABLE THIS SHEET
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL, AS REQUIRED BY MANUFACTURER'S INSTRUCTIONS.
* LONGITUDINAL ANCHORAGE (TYP.)
GROUND ANCHORS AND CONNECTION HARDWARE–(STRAPS ARE SHOWN OFFSET FOR CLARITY).
2'–0" (MAX)
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.
GA90–2
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
16"X16" DRY–STACK CMU PIER
24"X24" CONCRETE FOOTING

PIER STRAP PLAN
(FLOOD VELOCITIES UP TO 5 FT/SEC)
SEE SHEET APD 1.1
FOR PIER DESIGN

PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft²)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-3"	4'-9"	4'-2"	7'-10"	7'-2"	6'-6"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

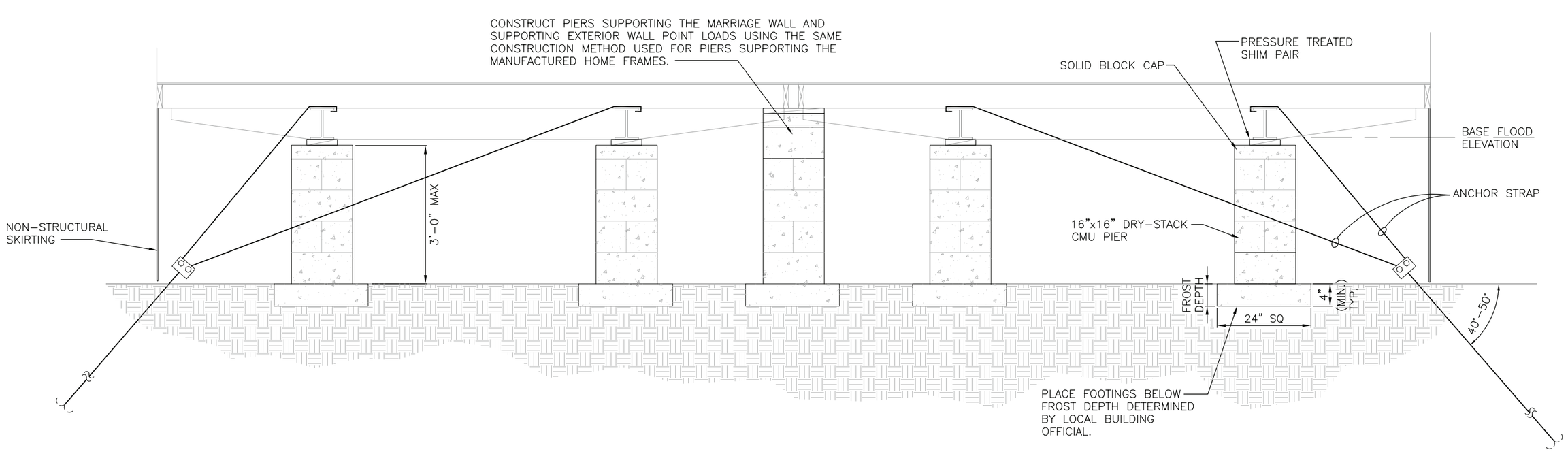
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 3,150 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS

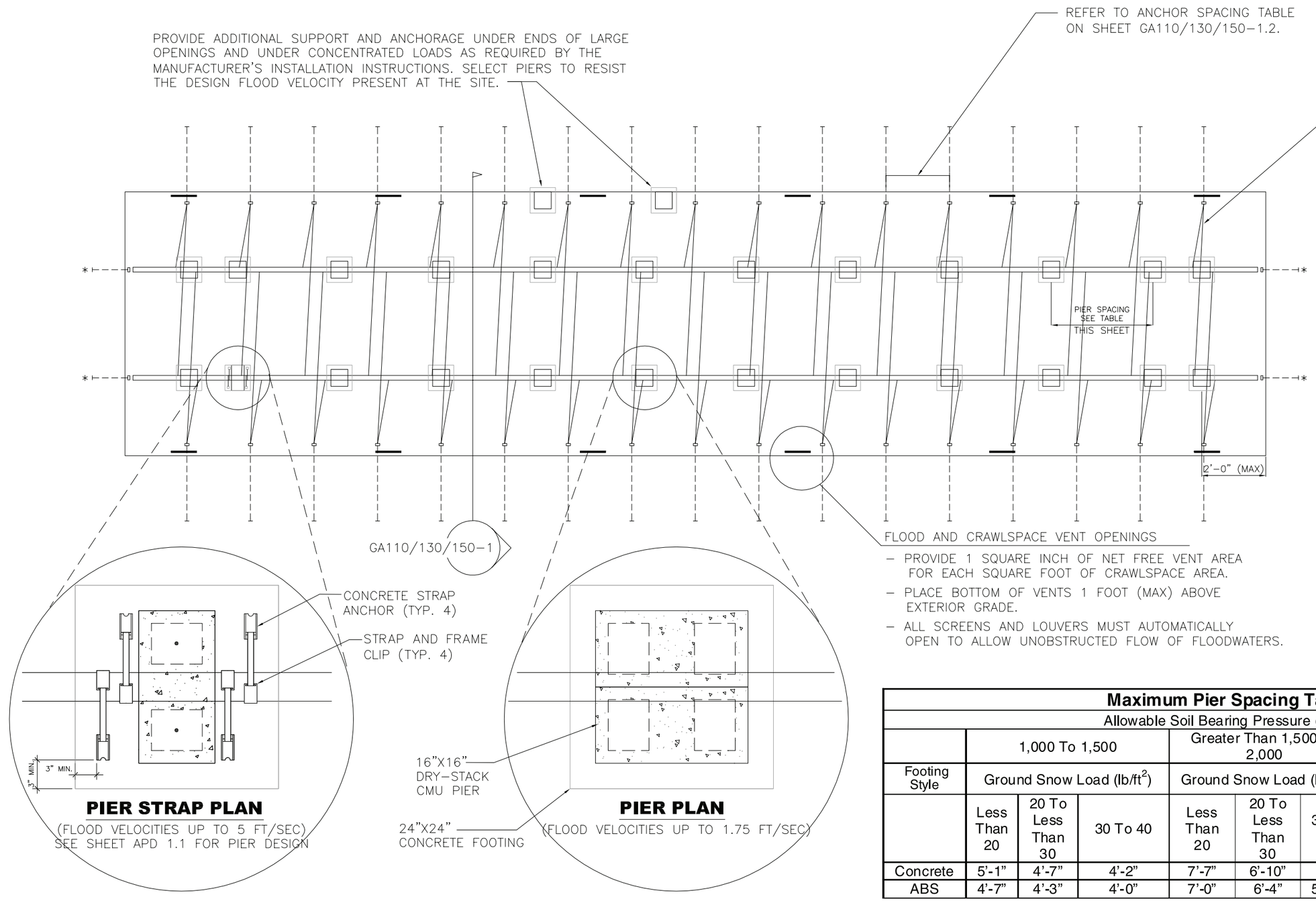

CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.
PRESSURE TREATED SHIM PAIR
SOLID BLOCK CAP
BASE FLOOD ELEVATION
ANCHOR STRAP
NON–STRUCTURAL SKIRTING
3'–0" MAX
16"x16" DRY–STACK CMU PIER
FROST DEPTH
4" (MIN.) TYP.
24" SQ
40°–50°
PLACE FOOTINGS BELOW FROST DEPTH DETERMINED BY LOCAL BUILDING OFFICIAL.

GA90–2

GROUND ANCHOR AND PIER DETAIL (DOUBLE UNIT)

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
REFER TO ANCHOR SPACING TABLE ON SHEET GA110/130/150–1.2.
GROUND ANCHORS AND CONNECTION HARDWARE–(STRAPS ARE SHOWN OFFSET FOR CLARITY).
PIER SPACING SEE TABLE THIS SHEET
* LONGITUDINAL ANCHORAGE (TYP.)
2'–0" (MAX)
GA110/130/150–1
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
PIER STRAP PLAN
(FLOOD VELOCITIES UP TO 5 FT/SEC)
SEE SHEET APD 1.1 FOR PIER DESIGN
16"X16" DRY–STACK CMU PIER
24"X24" CONCRETE FOOTING
PIER PLAN
(FLOOD VELOCITIES UP TO 1.75 FT/SEC)
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

Maximum Pier Spacing Table

	Allowable Soil Bearing Pressure (lb/ft^2)								
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater Than 2,000		
Footing Style	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-1"	4'-7"	4'-2"	7'-7"	6'-10"	6'-4"	8'-0"	8'-0"	8'-0"
ABS	4'-7"	4'-3"	4'-0"	7'-0"	6'-4"	5'-10"	8'-0"	8'-0"	7'-10"

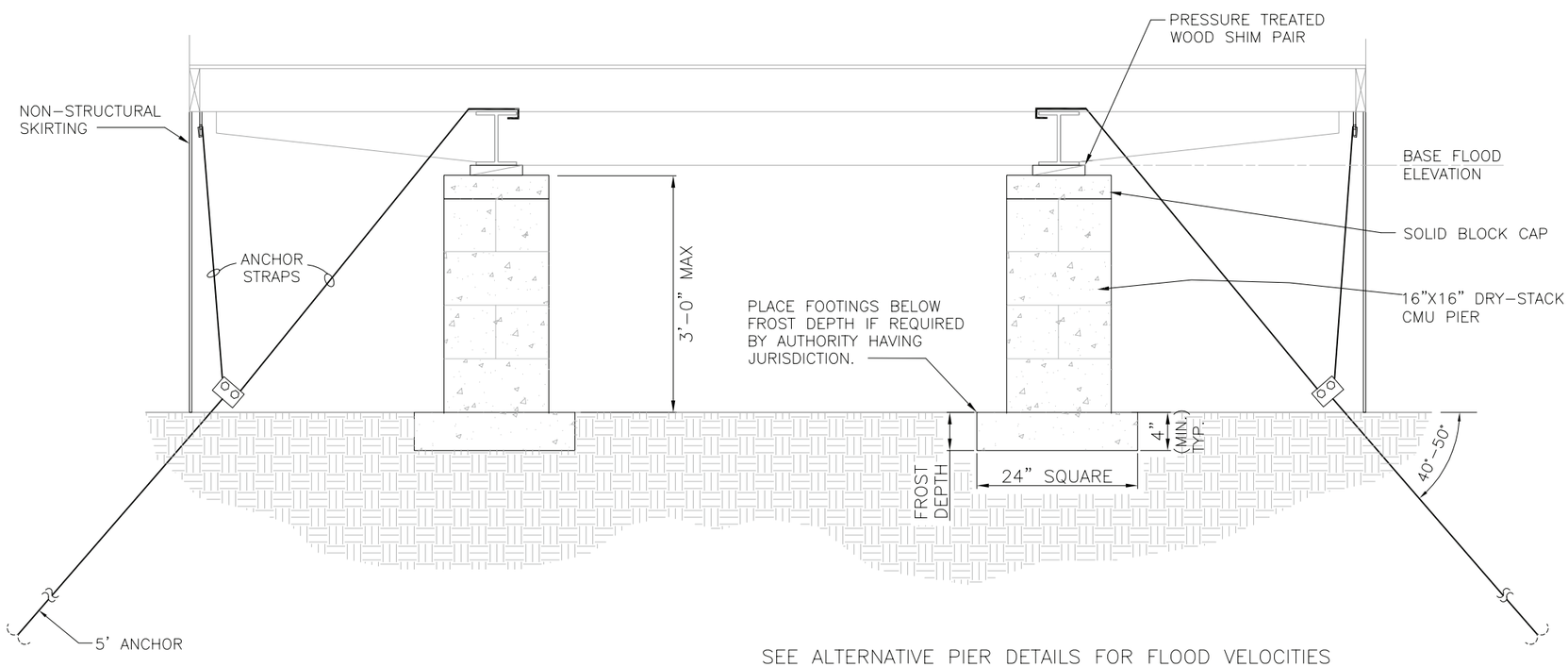
SINGLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 3,150 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS

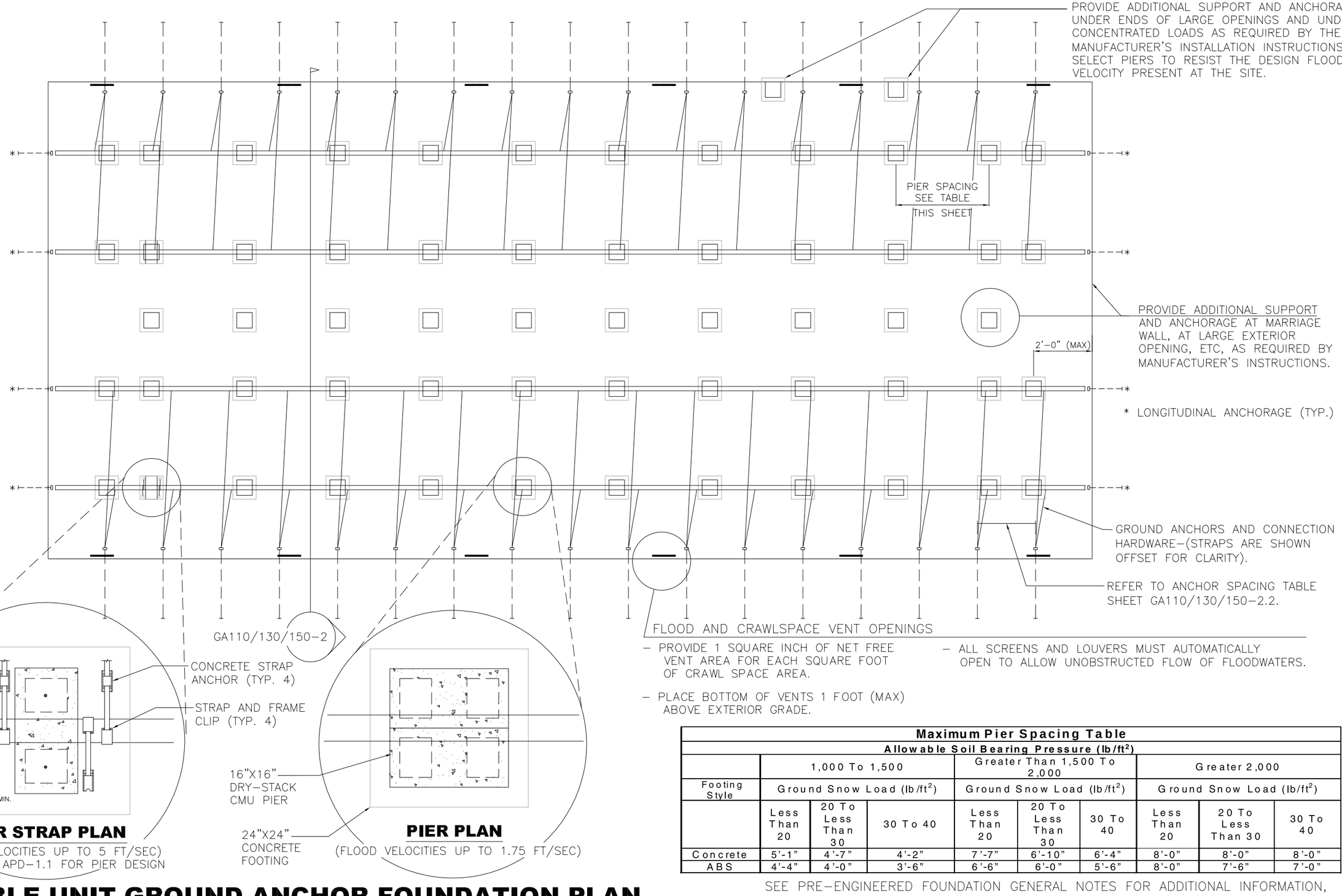


GA110/130/150–1

GROUND ANCHOR AND PIER DETAIL (SINGLE UNIT)

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE UNDER ENDS OF LARGE OPENINGS AND UNDER CONCENTRATED LOADS AS REQUIRED BY THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. SELECT PIERS TO RESIST THE DESIGN FLOOD VELOCITY PRESENT AT THE SITE.
PIER SPACING SEE TABLE THIS SHEET
PROVIDE ADDITIONAL SUPPORT AND ANCHORAGE AT MARRIAGE WALL, AT LARGE EXTERIOR OPENING, ETC, AS REQUIRED BY MANUFACTURER'S INSTRUCTIONS.
2'-0" (MAX)
* LONGITUDINAL ANCHORAGE (TYP.)
GROUND ANCHORS AND CONNECTION HARDWARE-(STRAPS ARE SHOWN OFFSET FOR CLARITY).
REFER TO ANCHOR SPACING TABLE SHEET GA110/130/150-2.2.
GA110/130/150-2
CONCRETE STRAP ANCHOR (TYP. 4)
STRAP AND FRAME CLIP (TYP. 4)
3" MIN.
3" MIN.
16"X16" DRY-STACK CMU PIER
24"X24" CONCRETE FOOTING

PIER STRAP PLAN

(FLOOD VELOCITIES UP TO 5 FT/SEC)
SEE SHEET APD-1.1 FOR PIER DESIGN

PIER PLAN

(FLOOD VELOCITIES UP TO 1.75 FT/SEC)

FLOOD AND CRAWLSPACE VENT OPENINGS

- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWL SPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

Maximum Pier Spacing Table

Allowable Soil Bearing Pressure (lb/ft²)									
	1,000 To 1,500			Greater Than 1,500 To 2,000			Greater 2,000		
Footing Style	Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
Concrete	5'-1"	4'-7"	4'-2"	7'-7"	6'-10"	6'-4"	8'-0"	8'-0"	8'-0"
ABS	4'-4"	4'-0"	3'-6"	6'-6"	6'-0"	5'-6"	8'-0"	7'-6"	7'-0"

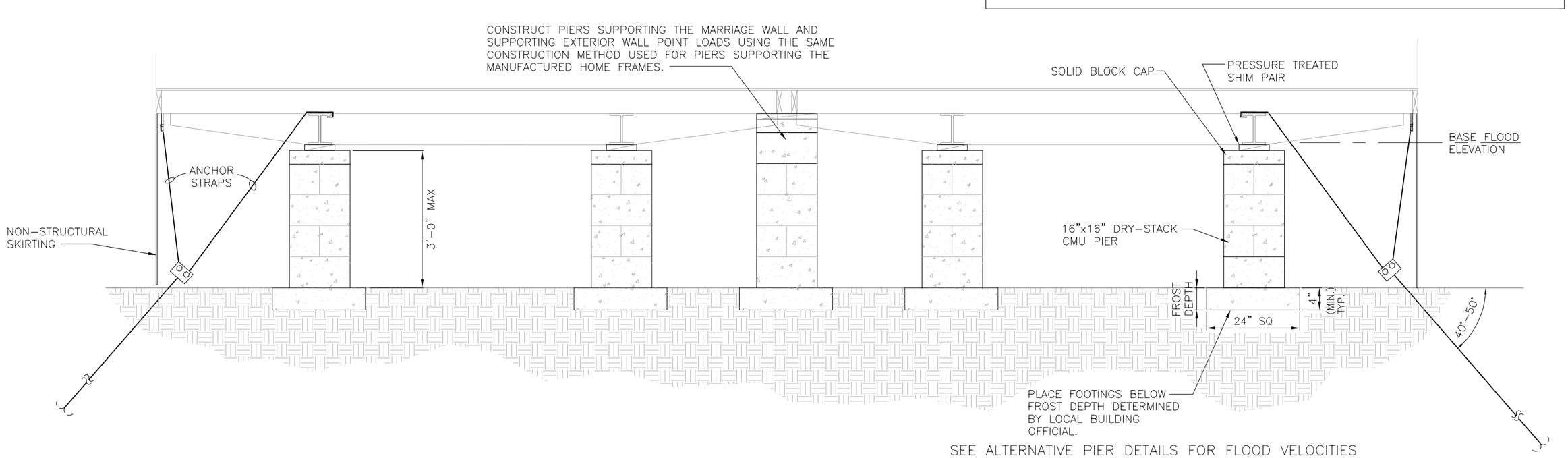
SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

DOUBLE UNIT GROUND ANCHOR FOUNDATION PLAN

NOT TO SCALE

ANCHOR SPACING

FOR STANDARD PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 3,150 LBS
FOR ALTERNATE PIER– PLEASE SEE TABLES IN SHEET AS1.1 WITH ANCHOR STRENGTH 2,000 LBS

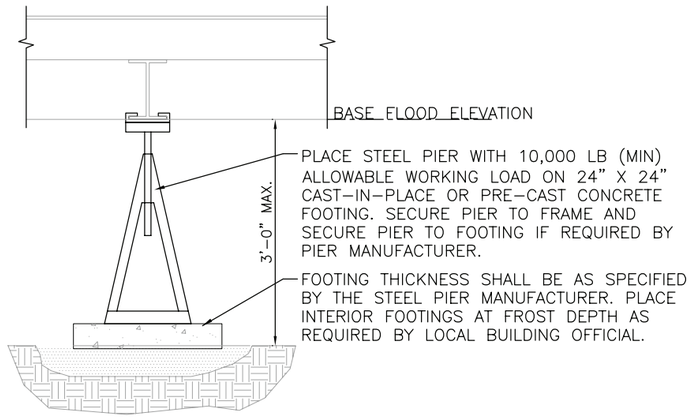

CONSTRUCT PIERS SUPPORTING THE MARRIAGE WALL AND SUPPORTING EXTERIOR WALL POINT LOADS USING THE SAME CONSTRUCTION METHOD USED FOR PIERS SUPPORTING THE MANUFACTURED HOME FRAMES.
SOLID BLOCK CAP
PRESSURE TREATED SHIM PAIR
BASE FLOOD ELEVATION
ANCHOR STRAPS
3'-0" MAX
NON-STRUCTURAL SKIRTING
16"x16" DRY-STACK CMU PIER
FROST DEPTH
4" (MIN.) TYP.
24" SQ
40°-50°
PLACE FOOTINGS BELOW FROST DEPTH DETERMINED BY LOCAL BUILDING OFFICIAL.

SEE ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES GREATER THAN 1.75 FPS. SHEET APD–1.1
SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

GA110/130/150–2

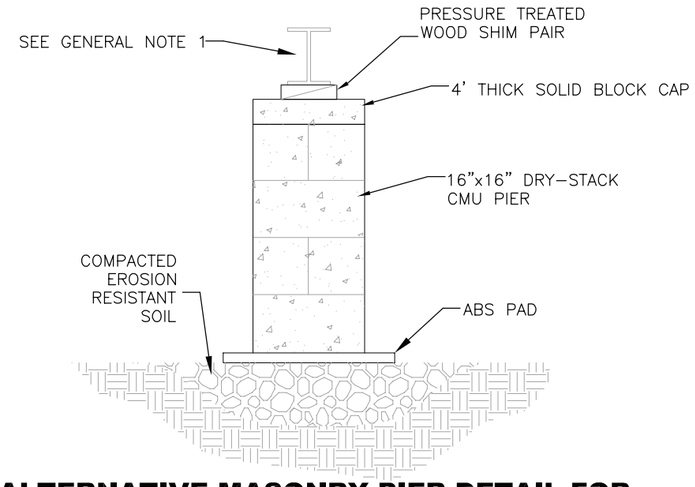
GROUND ANCHOR AND PIER DETAIL (DOUBLE UNIT)

NOT TO SCALE - PIER CONSTRUCTION FOR FLOOD VELOCITIES UP TO 1.75 FEET PER SECOND SHOWN


BASE FLOOD ELEVATION
PLACE STEEL PIER WITH 10,000 LB (MIN) ALLOWABLE WORKING LOAD ON 24" X 24" CAST-IN-PLACE OR PRE-CAST CONCRETE FOOTING. SECURE PIER TO FRAME AND SECURE PIER TO FOOTING IF REQUIRED BY PIER MANUFACTURER.
3'-0" MAX.
FOOTING THICKNESS SHALL BE AS SPECIFIED BY THE STEEL PIER MANUFACTURER. PLACE INTERIOR FOOTINGS AT FROST DEPTH AS REQUIRED BY LOCAL BUILDING OFFICIAL.

STEEL PIER

ALTERNATIVE FOR FLOOD VELOCITIES UP TO 1 FT/SEC


SEE GENERAL NOTE 1
PRESSURE TREATED WOOD SHIM PAIR
4' THICK SOLID BLOCK CAP
16"x16" DRY-STACK CMU PIER
COMPACTED EROSION RESISTANT SOIL
ABS PAD

ALTERNATIVE MASONRY PIER DETAIL FOR

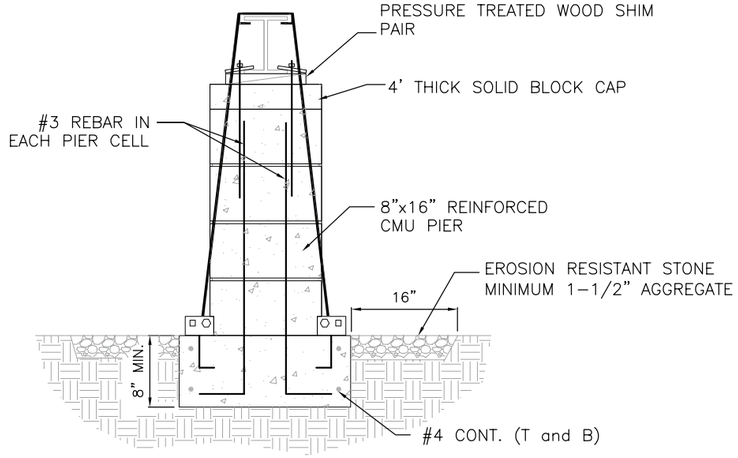
FLOOD VELOCITIES UP TO 1.25 FT/SEC

Table 1:Summary of Maximum Flood Velocities for Alternative Masonry pier Designs.[1]				
Masonry Pier Construction	Dry-Stack	Dry-Stack Face Mortar	Bonded[2] Stack	Fully Grouted, Reinforced and Anchored to Concrete Foundation
Single Stack	1.00 fps[3]	2.00 fps	2.50 fps	5.00 fps
Double Stack	1.25 fps[4] 1.75 fps	3.00 fps	3.00 fps	5.00 fps

[1]Velocities are the maximum design flood flow for each masonry block pier shown. Design velocity applicable to piers up to 36 inches high.
[2]Bonded piers use Type M or S Portland cement and lime mortar to adhere horizontal and vertical joints between block. Polyurethane based masonry adhesive certified by a recognized national agency for use in masonry construction in accordance with the IRC and IBC also may be used.
[3]Single block dry-stack pier design velocity applies to piers supported on ABS pads as well as concrete foundations.
[4]Design velocity of 1.25 fps applies to double block dry-stacked pier supported on ABS pad.

GENERAL NOTES

1. Pier may support manufactured home main frame beam or marriage wall.
2. Footing dimensions (W, L, and D) shall be as indicated on applicable foundation type detail sheets.

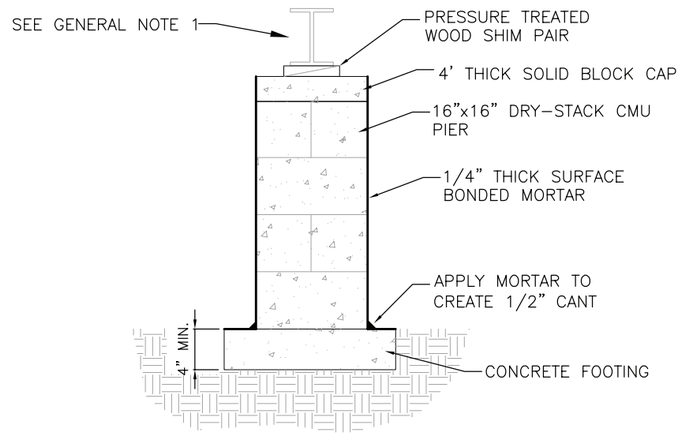

PRESSURE TREATED WOOD SHIM PAIR
4' THICK SOLID BLOCK CAP
#3 REBAR IN EACH PIER CELL
8"x16" REINFORCED CMU PIER
EROSION RESISTANT STONE MINIMUM 1-1/2" AGGREGATE
16"
8" MIN.
#4 CONT. (T and B)

ALTERNATIVE MASONRY PIER DETAIL FOR

FLOOD VELOCITIES UP TO 5 FT/SEC

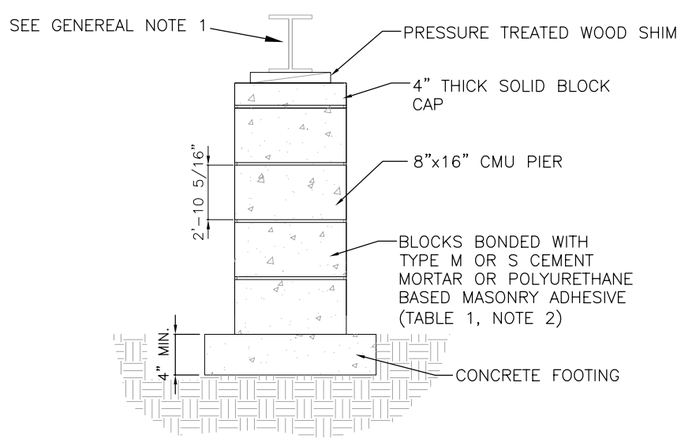
16" BY 8" MASONRY PIER AND CONCRETE FOOTING:
SECURE PIER, FOOTING, AND FRAME WITH STRAPS, FRAME CLIPS, AND CONCRETE ANCHORS. PROVIDE FRAME CLIP FOR EACH STRAP.

PROVIDE SCOUR PROTECTION AROUND PIERS IN AREAS WHERE FLOOD VELOCITIES EXCEED 3 FT/SEC USING NON-ERODIBLE SOILS OR BY PLACING FOOTINGS BELOW THE MAXIMUM SCOUR DEPTH FOR THE FLOOD VELOCITIES PRESENT.


SEE GENERAL NOTE 1
PRESSURE TREATED WOOD SHIM PAIR
4' THICK SOLID BLOCK CAP
16"x16" DRY-STACK CMU PIER
1/4" THICK SURFACE BONDED MORTAR
APPLY MORTAR TO CREATE 1/2" CANT
4" MIN.
CONCRETE FOOTING

ALTERNATIVE MASONRY PIER DETAIL FOR

FLOOD VELOCITIES UP TO 3 FT/SEC


SEE GENEREAL NOTE 1
PRESSURE TREATED WOOD SHIM
4" THICK SOLID BLOCK CAP
8"x16" CMU PIER
2'-10 5/16"
BLOCKS BONDED WITH TYPE M OR S CEMENT MORTAR OR POLYURETHANE BASED MASONRY ADHESIVE (TABLE 1, NOTE 2)
4" MIN.
CONCRETE FOOTING

ALTERNATIVE MASONRY PIER DETAIL FOR

FLOOD VELOCITIES UP TO 2.5 FT/SEC

ALTERNATIVE PIER DETAILS FOR FLOOD VELOCITIES NOT SHOWN ON PLANS

NOT TO SCALE

Maximum Ground Anchor Spacing Table:Design Wind Speed 90 mph

Anchor Strength (lbs)	Strap Connection Height (in)	Roof Pitch	Building Width - Single Unit						Building Width - Double Unit					
			12 ft		14 ft		16 ft		24 ft		28 ft		32 ft	
			I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)	
			82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5
1500	25	3:12	9'-0"	9'-3"	9'-4"	9'-7"	9'-9"	9'-10"	8'-9"	7'-1"	10'-3"	9'-4"	11'-1"	10'-7"
		5:12	9'-1"	9'-3"	9'-6"	9'-8"	9'-8"	9'-10"	7'-4"	6'-0"	8'-4"	7'-8"	8'-9"	8'-6"
		7:12	8'-6"	8'-8"	8'-8"	8'-10"	8'-9"	9'-0"	6'-6"	5'-3"	7'-2"	6'-7"	7'-6"	7'-2"
	33	3:12	8'-8"	8'-10"	9'-1"	9'-3"	9'-6"	9'-8"	7'-7"	5'-10"	9'-3"	8'-3"	10'-4"	9'-9"
		5:12	8'-9"	9'-0"	9'-2"	9'-4"	9'-6"	9'-8"	6'-4"	4'-10"	7'-7"	6'-8"	8'-2"	7'-8"
		7:12	8'-2"	8'-6"	8'-6"	8'-8"	8'-7"	8'-9"	5'-7"	4'-3"	6'-7"	5'-9"	7'-0"	6'-7"
2000	25	3:12	12'-0"	12'-3"	12'-7"	12'-9"	13'-0"	13'-2"	11'-9"	9'-6"	13'-8"	12'-7"	14'-9"	14'-2"
		5:12	12'-1"	12'-4"	12'-7"	12'-10"	13'-0"	13'-2"	9'-10"	8'-0"	11'-2"	10'-3"	11'-9"	11'-3"
		7:12	11'-3"	11'-7"	11'-7"	11'-10"	11'-9"	12'-0"	8'-8"	7'-0"	9'-8"	8'-10"	10'-0"	9'-7"
	33	3:12	11'-7"	11'-10"	12'-2"	12'-4"	12'-7"	12'-10"	10'-2"	7'-9"	12'-4"	11'-0"	13'-9"	13'-0"
		5:12	11'-8"	12'-1"	12'-2"	12'-6"	12'-7"	12'-10"	8'-6"	6'-6"	10'-1"	9'-0"	11'-0"	10'-3"
		7:12	10'-10"	11'-3"	11'-3"	11'-7"	11'-6"	11'-9"	7'-6"	5'-8"	8'-9"	7'-9"	9'-3"	8'-9"
2500	25	3:12	15'-1"	15'-4"	15'-8"	16'-0"	16'-3"	16'-6"	14'-8"	11'-10"	16'-0"	15'-8"	16'-0"	16'-0"
		5:12	15'-2"	15'-7"	15'-9"	16'-1"	16'-2"	16'-6"	12'-4"	10'-0"	14'-0"	12'-9"	14'-8"	14'-1"
		7:12	14'-1"	14'-6"	14'-6"	14'-9"	14'-8"	15'-0"	10'-9"	8'-9"	12'-1"	11'-1"	12'-6"	12'-0"
	33	3:12	14'-6"	14'-10"	15'-2"	15'-7"	15'-9"	16'-0"	12'-8"	9'-9"	15'-6"	13'-9"	16'-0"	16'-0"
		5:12	14'-7"	15'-1"	15'-3"	15'-8"	15'-9"	16'-0"	10'-7"	8'-2"	12'-8"	11'-2"	13'-8"	12'-10"
		7:12	13'-8"	14'-1"	14'-1"	14'-6"	14'-4"	14'-8"	9'-3"	7'-2"	10'-10"	9'-8"	11'-8"	11'-0"
3150	25	3:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	15'-0"	16'-0"	16'-0"	16'-0"	16'-0"
		5:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	15'-7"	12'-7"	16'-0"	16'-0"	16'-0"	16'-0"
		7:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	13'-8"	11'-0"	15'-2"	14'-0"	15'-8"	15'-1"
	33	3:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	12'-3"	16'-0"	16'-0"	16'-0"	16'-0"
		5:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	13'-4"	10'-3"	16'-0"	14'-2"	16'-0"	16'-0"
		7:12	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	16'-0"	11'-9"	9'-0"	13'-9"	12'-2"	14'-8"	13'-9"

Maximum Ground Anchor Spacing Table:Design Wind Speed 110 mph

Anchor Strength (lbs)	Strap Connection Height (in)	Roof Pitch	Building Width - Single Unit						Building Width - Double Unit					
			12 ft		14 ft		16 ft		24 ft		28 ft		32 ft	
			I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)	
			82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5
1500	25	3:12	5'-7"	5'-8"	5'-10"	5'-8"	6'-1"	5'-8"	7'-3"	7'-4"	7'-4"	7'-4"	7'-4"	7'-6"
		5:12	5'-8"	5'-9"	5'-10"	5'-9"	6'-1"	5'-9"	6'-8"	6'-8"	6'-7"	6'-7"	6'-6"	6'-7"
		7:12	5'-3"	5'-4"	5'-6"	5'-4"	5'-7"	5'-4"	5'-10"	6'-0"	5'-9"	5'-9"	5'-7"	5'-7"
	33	3:12	5'-4"	5'-6"	5'-8"	5'-6"	5'-10"	5'-6"	7'-2"	7'-4"	7'-3"	7'-4"	7'-4"	7'-4"
		5:12	5'-6"	5'-6"	5'-8"	5'-6"	5'-10"	5'-6"	6'-8"	6'-8"	6'-7"	6'-7"	6'-6"	6'-7"
		7:12	5'-1"	5'-2"	5'-3"	5'-2"	5'-6"	5'-2"	5'-10"	6'-0"	5'-8"	5'-9"	5'-7"	5'-7"
2000	25	3:12	7'-6"	7'-7"	7'-9"	7'-7"	8'-1"	7'-7"	9'-8"	9'-10"	9'-9"	9'-10"	9'-10"	10'-0"
		5:12	7'-7"	7'-8"	7'-10"	7'-8"	8'-2"	7'-8"	8'-10"	9'-0"	8'-9"	8'-10"	8'-8"	8'-8"
		7:12	7'-1"	7'-2"	7'-3"	7'-2"	7'-6"	7'-2"	7'-10"	7'-10"	7'-8"	7'-8"	7'-6"	7'-6"
	33	3:12	7'-2"	7'-3"	7'-7"	7'-3"	7'-9"	7'-3"	9'-7"	9'-10"	9'-8"	9'-10"	9'-10"	9'-10"
		5:12	7'-3"	7'-4"	7'-8"	7'-4"	7'-10"	7'-4"	8'-10"	9'-0"	8'-9"	8'-9"	8'-8"	8'-8"
		7:12	6'-9"	7'-0"	7'-1"	7'-0"	7'-3"	7'-0"	7'-10"	7'-10"	7'-8"	7'-8"	7'-4"	7'-6"
2500	25	3:12	9'-4"	9'-6"	9'-9"	9'-6"	10'-1"	9'-6"	12'-1"	12'-4"	12'-3"	12'-4"	12'-4"	12'-6"
		5:12	9'-6"	9'-7"	9'-10"	9'-7"	10'-2"	9'-7"	11'-1"	11'-2"	11'-0"	11'-1"	10'-10"	10'-10"
		7:12	8'-10"	9'-0"	9'-2"	9'-0"	9'-4"	9'-0"	9'-10"	9'-10"	9'-7"	9'-7"	9'-3"	9'-3"
	33	3:12	9'-0"	9'-1"	9'-6"	9'-1"	9'-9"	9'-1"	12'-1"	12'-4"	12'-2"	12'-3"	12'-3"	12'-4"
		5:12	9'-1"	9'-2"	9'-7"	9'-2"	9'-10"	9'-2"	11'-1"	11'-2"	11'-0"	11'-1"	10'-10"	10'-10"
		7:12	8'-7"	8'-8"	8'-10"	8'-8"	9'-1"	8'-8"	9'-9"	9'-10"	9'-7"	9'-7"	9'-3"	9'-3"
3150	25	3:12	11'-9"	11'-10"	12'-3"	11'-10"	12'-8"	11'-10"	15'-3"	15'-7"	15'-4"	15'-7"	15'-7"	15'-8"
		5:12	12'-0"	12'-1"	12'-6"	12'-1"	12'-10"	12'-1"	14'-0"	14'-2"	13'-10"	13'-10"	13'-9"	13'-9"
		7:12	11'-2"	11'-4"	11'-7"	11'-4"	11'-9"	11'-4"	12'-4"	12'-6"	12'-1"	12'-1"	11'-8"	11'-8"
	33	3:12	11'-4"	11'-6"	11'-10"	11'-6"	12'-4"	11'-6"	15'-2"	15'-7"	15'-3"	15'-6"	15'-6"	15'-7"
		5:12	11'-6"	11'-7"	12'-0"	11'-7"	12'-6"	11'-7"	14'-0"	14'-2"	13'-10"	13'-10"	13'-8"	13'-9"
		7:12	10'-9"	11'-0"	11'-2"	11'-0"	11'-6"	11'-0"	12'-4"	12'-6"	12'-1"	12'-1"	11'-8"	11'-8"

Maximum Ground Anchor Spacing Table:Design Wind Speed 130 mph

Anchor Strength (lbs)	Strap Connection Height (in)	Roof Pitch	Building Width - Single Unit						Building Width - Double Unit					
			12 ft		14 ft		16 ft		24 ft		28 ft		32 ft	
			I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)	
			82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5
1500	25	3:12	3'-10"	3'-10"	4'-0"	3'-10"	4'-2"	3'-10"	4'-8"	4'-9"	4'-8"	4'-9"	4'-8"	4'-8"
		5:12	3'-10"	4'-0"	4'-1"	4'-0"	4'-2"	4'-0"	4'-7"	4'-7"	4'-6"	4'-7"	4'-6"	4'-6"
		7:12	3'-8"	3'-8"	3'-9"	3'-8"	3'-10"	3'-8"	4'-1"	4'-2"	4'-0"	4'-0"	3'-10"	3'-10"
	33	3:12	3'-8"	3'-8"	3'-10"	3'-8"	4'-0"	3'-8"	4'-8"	4'-10"	4'-8"	4'-8"	4'-8"	4'-8"
		5:12	3'-9"	3'-9"	4'-0"	3'-9"	4'-1"	3'-9"	4'-7"	4'-8"	4'-6"	4'-7"	4'-6"	4'-6"
		7:12	3'-7"	3'-7"	3'-8"	3'-7"	3'-9"	3'-7"	4'-1"	4'-2"	4'-0"	4'-0"	3'-10"	3'-10"
2000	25	3:12	5'-2"	5'-2"	5'-4"	5'-2"	5'-6"	5'-2"	6'-3"	6'-6"	6'-3"	6'-4"	6'-3"	6'-3"
		5:12	5'-2"	5'-3"	5'-6"	5'-3"	5'-7"	5'-3"	6'-1"	6'-2"	6'-0"	6'-1"	6'-0"	6'-0"
		7:12	4'-10"	5'-0"	5'-1"	5'-0"	5'-2"	5'-0"	5'-6"	5'-7"	5'-3"	5'-4"	5'-2"	5'-2"
	33	3:12	5'-0"	5'-0"	5'-2"	5'-0"	5'-4"	5'-0"	6'-3"	6'-6"	6'-3"	6'-3"	6'-3"	6'-3"
		5:12	5'-0"	5'-1"	5'-3"	5'-1"	5'-6"	5'-1"	6'-1"	6'-2"	6'-0"	6'-1"	6'-0"	6'-0"
		7:12	4'-8"	4'-9"	4'-10"	4'-9"	5'-0"	4'-9"	5'-6"	5'-7"	5'-3"	5'-4"	5'-2"	5'-2"
2500	25	3:12	6'-6"	6'-6"	6'-8"	6'-6"	6'-10"	6'-6"	7'-10"	8'-1"	7'-10"	7'-10"	7'-10"	7'-10"
		5:12	6'-7"	6'-7"	6'-9"	6'-7"	7'-0"	6'-7"	7'-7"	7'-8"	7'-7"	7'-7"	7'-6"	7'-6"
		7:12	6'-2"	6'-2"	6'-4"	6'-2"	6'-6"	6'-2"	6'-10"	6'-10"	6'-8"	6'-8"	6'-6"	6'-7"
	33	3:12	6'-2"	6'-2"	6'-6"	6'-2"	6'-8"	6'-2"	7'-10"	8'-1"	7'-9"	7'-10"	7'-9"	7'-9"
		5:12	6'-3"	6'-3"	6'-7"	6'-3"	6'-9"	6'-3"	7'-7"	7'-9"	7'-6"	7'-7"	7'-6"	7'-6"
		7:12	5'-10"	6'-0"	6'-1"	6'-0"	6'-3"	6'-0"	6'-9"	7'-0"	6'-8"	6'-8"	6'-6"	6'-6"
3150	25	3:12	8'-1"	8'-2"	8'-6"	8'-2"	8'-8"	8'-2"	10'-0"	10'-2"	10'-0"	10'-0"	9'-10"	9'-10"
		5:12	8'-3"	8'-3"	8'-7"	8'-3"	8'-10"	8'-3"	9'-7"	9'-9"	9'-6"	9'-7"	9'-6"	9'-6"
		7:12	7'-9"	7'-10"	8'-0"	7'-10"	8'-2"	7'-10"	8'-7"	8'-8"	8'-4"	8'-6"	8'-2"	8'-3"
	33	3:12	7'-9"	7'-9"	8'-2"	7'-9"	8'-6"	7'-9"	9'-10"	10'-2"	9'-10"	10'-0"	9'-10"	9'-10"
		5:12	7'-10"	8'-0"	8'-3"	8'-0"	8'-7"	8'-0"	9'-7"	9'-9"	9'-6"	9'-7"	9'-4"	9'-4"
		7:12	7'-6"	7'-7"	7'-8"	7'-7"	7'-10"	7'-7"	8'-7"	8'-9"	8'-4"	8'-6"	8'-2"	8'-2"

Maximum Ground Anchor Spacing Table:Design Wind Speed 150 mph

Anchor Strength (lbs)	Strap Connection Height (in)	Roof Pitch	Building Width - Single Unit						Building Width - Double Unit					
			12 ft		14 ft		16 ft		24 ft		28 ft		32 ft	
			I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)		I-Beam Spacing (in)	
			82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5	82.5	99.5
1500	25	3:12	2'-9"	2'-9"	2'-10"	2'-9"	3'-0"	2'-9"	3'-3"	3'-4"	3'-3"	3'-3"	3'-3"	3'-3"
		5:12	2'-10"	2'-10"	3'-0"	2'-10"	3'-1"	2'-10"	3'-3"	3'-4"	3'-3"	3'-3"	3'-2"	3'-2"
		7:12	2'-8"	2'-8"	2'-9"	2'-8"	2'-10"	2'-8"	3'-0"	3'-0"	2'-10"	2'-10"	2'-10"	2'-10"
	33	3:12	2'-8"	2'-8"	2'-9"	2'-8"	2'-10"	2'-8"	3'-3"	3'-4"	3'-3"	3'-3"	3'-2"	3'-2"
		5:12	2'-9"	2'-9"	2'-10"	2'-9"	3'-0"	2'-9"	3'-3"	3'-4"	3'-2"	3'-3"	3'-2"	3'-2"
		7:12	2'-7"	2'-7"	2'-8"	2'-7"	2'-9"	2'-7"	3'-0"	3'-1"	2'-10"	2'-10"	2'-9"	2'-10"
2000	25	3:12	3'-9"	3'-9"	3'-10"	3'-9"	4'-0"	3'-9"	4'-6"	4'-6"	4'-4"	4'-4"	4'-4"	4'-4"
		5:12	3'-9"	3'-10"	4'-0"	3'-10"	4'-1"	3'-10"	4'-4"	4'-6"	4'-4"	4'-4"	4'-3"	4'-3"
		7:12	3'-7"	3'-8"	3'-8"	3'-8"	3'-9"	3'-8"	4'-0"	4'-1"	3'-10"	3'-10"	3'-9"	3'-9"
	33	3:12	3'-7"	3'-7"	3'-9"	3'-7"	3'-10"	3'-7"	4'-4"	4'-6"	4'-4"	4'-4"	4'-3"	4'-3"
		5:12	3'-8"	3'-8"	3'-10"	3'-8"	4'-0"	3'-8"	4'-4"	4'-6"	4'-3"	4'-4"	4'-3"	4'-3"
		7:12	3'-6"	3'-6"	3'-7"	3'-6"	3'-8"	3'-6"	4'-0"	4'-1"	3'-10"	3'-10"	3'-9"	3'-9"
2500	25	3:12	4'-8"	4'-8"	4'-10"	4'-8"	5'-1"	4'-8"	5'-7"	5'-8"	5'-6"	5'-6"	5'-6"	5'-4"
		5:12	4'-9"	4'-9"	5'-0"	4'-9"	5'-2"	4'-9"	5'-6"	5'-7"	5'-4"	5'-6"	5'-4"	5'-4"
		7:12	4'-6"	4'-7"	4'-8"	4'-7"	4'-9"	4'-7"	5'-0"	5'-1"	4'-10"	4'-10"	4'-9"	4'-9"
	33	3:12	4'-6"	4'-6"	4'-8"	4'-6"	4'-10"	4'-6"	5'-6"	5'-8"	5'-6"	5'-6"	5'-4"	5'-4"
		5:12	4'-7"	4'-7"	4'-9"	4'-7"	5'-0"	4'-7"	5'-6"	5'-7"	5'-4"	5'-6"	5'-4"	5'-4"
		7:12	4'-4"	4'-4"	4'-6"	4'-4"	4'-7"	4'-4"	5'-0"	5'-1"	4'-10"	4'-10"	4'-8"	4'-9"
3150	25	3:12	6'-0"	6'-0"	6'-2"	6'-0"	6'-4"	6'-0"	7'-0"	7'-1"	6'-10"	7'-0"	6'-10"	6'-10"
		5:12	6'-1"	6'-1"	6'-3"	6'-1"	6'-6"	6'-1"	6'-10"	7'-1"	6'-10"	6'-10"	6'-9"	6'-9"
		7:12	5'-8"	5'-9"	5'-10"	5'-9"	6'-0"	5'-9"	6'-3"	6'-4"	6'-1"	6'-2"	6'-0"	6'-0"
	33	3:12	5'-8"	5'-8"	6'-0"	5'-8"	6'-2"	5'-8"	7'-0"	7'-2"	6'-10"	6'-10"	6'-9"	6'-9"
		5:12	5'-9"	5'-9"	6'-1"	5'-9"	6'-3"	5'-9"	6'-10"	7'-1"	6'-9"	6'-10"	6'-9"	6'-9"
		7:12	5'-6"	5'-6"	5'-8"	5'-6"	5'-9"	5'-6"	6'-3"	6'-4"	6'-1"	6'-2"	6'-0"	6'-0"

NOTES: 1.RECOMMENDED ANCHOR SPACING IS GIVEN IN FEET AND INCHES.
2.SEE SHEET AS 1.2 FOR ADDITIONAL GROUND ANCHOR NOTES.
3.SEE SHEET GN-1.1 FOR GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

LATERAL GROUND ANCHOR SPACING

Longitudinal Ground Anchors – Number of Anchors @ Each Building End							
		Building Width – Single Unit			Building Width – Double Unit		
Design Wind Speed (mph)	Anchor Strength (Pounds)	12 ft.	14 ft.	16 ft.	24 ft.	28 ft.	32 ft.
90	1,500	2	2	2	3	4	4
	2,000	2	2	2	3	3	4
	2,500	1	2	2	2	3	3
	3,150	1	1	1	2	2	2
110	1,500	3	3	3	5	6	6
	2,000	2	3	3	4	4	4
	2,500	2	2	2	3	4	4
	3,150	2	2	2	3	3	3
130	1,500	4	4	4	7	7	7
	2,000	3	4	4	5	6	7
	2,500	2	3	3	4	5	5
	3,150	2	2	2	3	4	4
150	1,500	5	5	6	9	10	12
	2,000	4	4	5	7	8	9
	2,500	3	3	4	6	6	7
	3,150	2	3	3	4	5	6

Ground Anchor Notes

1. Maximum recommended ground anchor spacing is 16 feet for both lateral and longitudinal applications.

2. Minimum recommended spacing between ground anchors is 2 ft. 8 in. to minimize soil stress overlap of adjacent anchors. For anchors closer than 2 ft. 8 in. use alternative support and anchorage system unless manufacturer certifies ground anchor capacity for the required spacing.

3. Recommended ground anchor spacing is based on wind Exposure C conditions for basic wind speed conditions specified in ASCE/SEI 7-05.

4. Recommended ground anchor spacing is based on manufactured home with 8ft. wall height, 1ft. eave overhang and a minimum average weight of 20 pounds per square foot.

5. Ground anchors must be located within 2 ft. of the exterior walls of the manufactured home.

6. Linear interpolation between I-beam spacing is permitted.

Longitudinal Ground Anchor Spacing and Anchor Notes

NOT TO SCALE

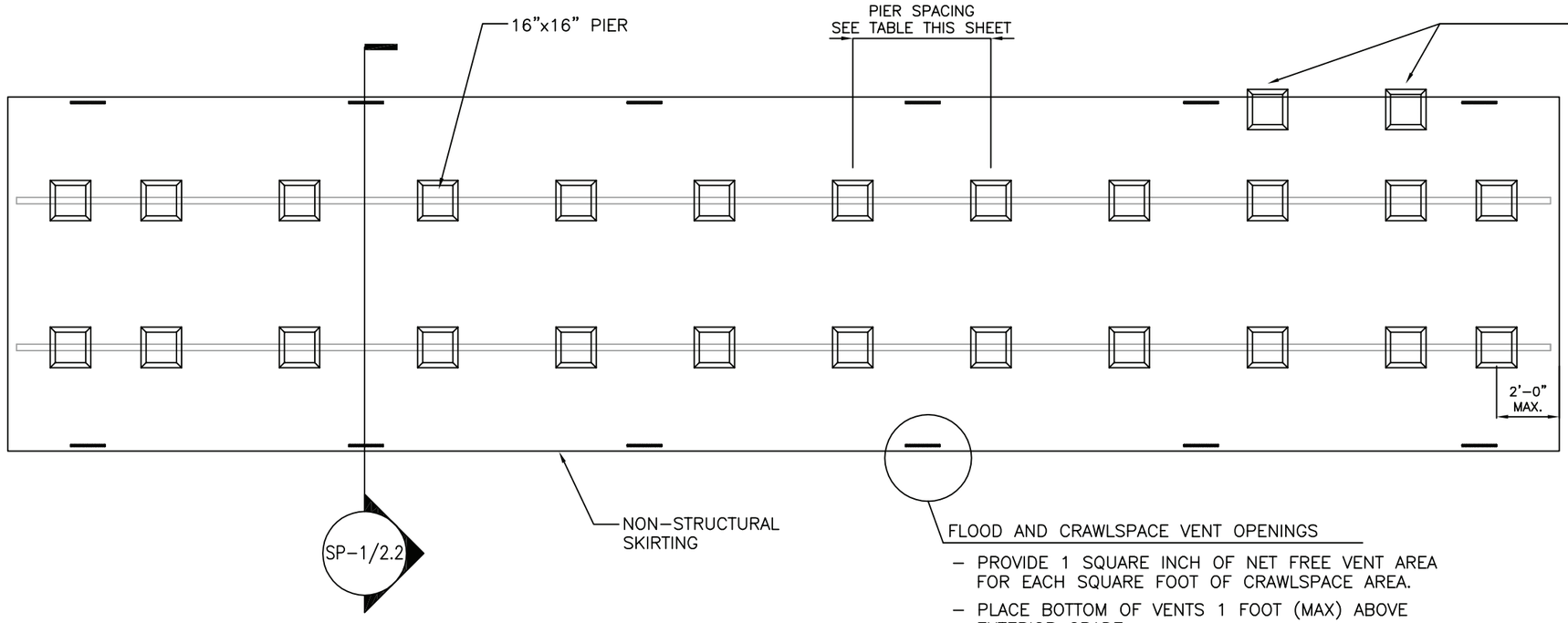

16"x16" PIER
PIER SPACING
SEE TABLE THIS SHEET
PROVIDE ADDITIONAL SUPPORT AND ACHORAGE AT LARGE WALL OPENINGS AND AT MARRIAGE WALLS (IN MULTIPLE SECTION HOMES) AS REQUIRED BY MANUFACTURER'S INSTALLATION INSTRUCTIONS.
2'-0" MAX.
SP-1/2.2
NON-STRUCTURAL SKIRTING
FLOOD AND CRAWLSPACE VENT OPENINGS
- PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
- PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
- ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

Table SP-1.1 Pier Minimum Square Footing Side Dimension and Depth[1,2]

Width	Pier Height (ft)[3]	Pier Spacing Along Chassis (ft)	Allowable Soil Bearing Pressure (psf)		
			1000	1500	2000
Seismic or 90 mph Wind - Flood Velocities 0 to 2fps					
single	3	4	3'-0" x 3'-0" x 16"	-	-
		7	4'-0" x 4'-0" x 20"	-	-
		10	4'-6" x 4'-6" x 20"	4'-0" x 4'-0" x 20"	-
double	3	4	3'-0" x 3'-0" x 16"	2'-6" x 2'-6" x 16"	-
		7	3'-6" x 3'-6" x 20"	-	-
		10	4'-0" x 4'-0" x 20"	-	-
single	5	4	3'-6" x 3'-6" x 20"	-	-
		7	4'-6" x 4'-6" x 20"	4'-0" x 4'-0" x 20"	-
		10	5'-0" x 5'-0" x 20"	4'-6" x 4'-6" x 20"	-
double	5	4	3'-0" x 3'-0" x 16"	-	-
		7	3'-6" x 3'-6" x 20"	-	-
		10	4'-0" x 4'-0" x 20"	-	-
90 mph Wind Plus Non-Coastal A-Zone Flood[4] - Flood Velocities 2+ to 5 fps					
single	3	4	3'-6" x 3'-6" x 20"	-	-
		7	4'-0" x 4'-0" x 20"	-	-
		10	4'-6" x 4'-6" x 20"	-	-
double	3	4	3'-0" x 3'-0" x 16"	-	-
		7	4'-0" x 4'-0" x 20"	-	-
		10	4'-6" x 4'-6" x 20"	-	-
single	5	4	4'-0" x 4'-0" x 20"	-	3'-6" x 3'-6" x 20"
		7	4'-6" x 4'-6" x 20"	-	-
		10	5'-0" x 5'-0" x 20"	-	-
double	5	4	3'-6" x 3'-6" x 20"	-	-
		7	4'-0" x 4'-0" x 20"	-	-
		10	4'-6" x 4'-6" x 20"	-	-

[1] Top of concrete footing shall not extend above finished grade. Provide greater footing depth where required to satisfy local frost depth requirements. Circular footing of equal area permitted, with minimum diameter equal to 1.13 times tabulated side dimension.

[2] Increase footing depth or provide erosion protection around piers in flood hazard areas where the maximum predicted scour depth exceeds 16 in (406 mm).

[3] Pier height measured from top of grade.

[4] Flood velocities not greater than 5 ft/sec (1.52 m/sec) with depths not exceeding the elevation of the lowest edge of the longitudinal support frame.

NOTE: THIS DESIGN IS SUITABLE FOR 3-SECOND GUST DESIGN AND SPEEDS UP TO 90 MILES PER HOUR.

"IF FOOTING SIZE NOT SHOWN FOR SITE SPECIFIC ALLOWABLE BEARING PRESSURE, USE THE FOOTING SIZE FOR NEXT LOWEST ALLOWABLE BEARING PRESSURE."

SINGLE UNIT CONCRETE MASONRY PIER FOUNDATION PLAN

NOT TO SCALE

SEE PRE-ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN-1.1

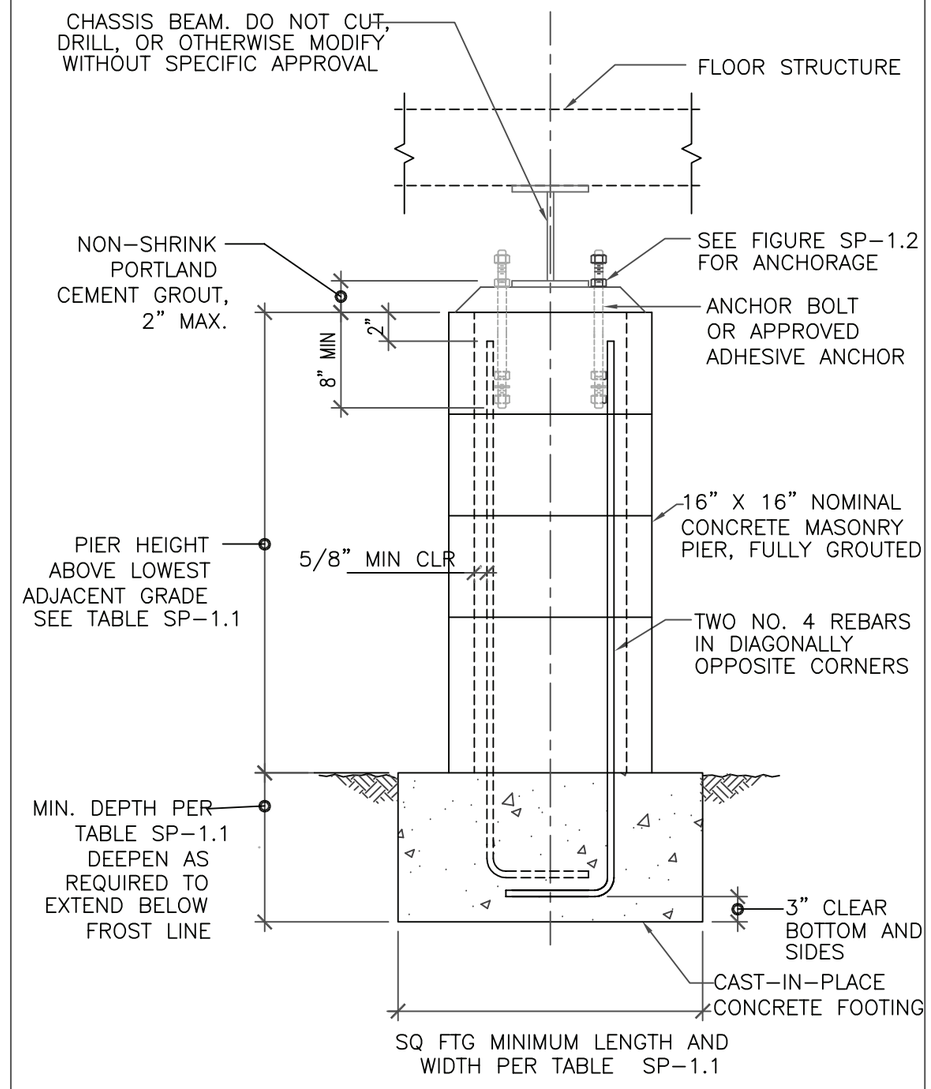
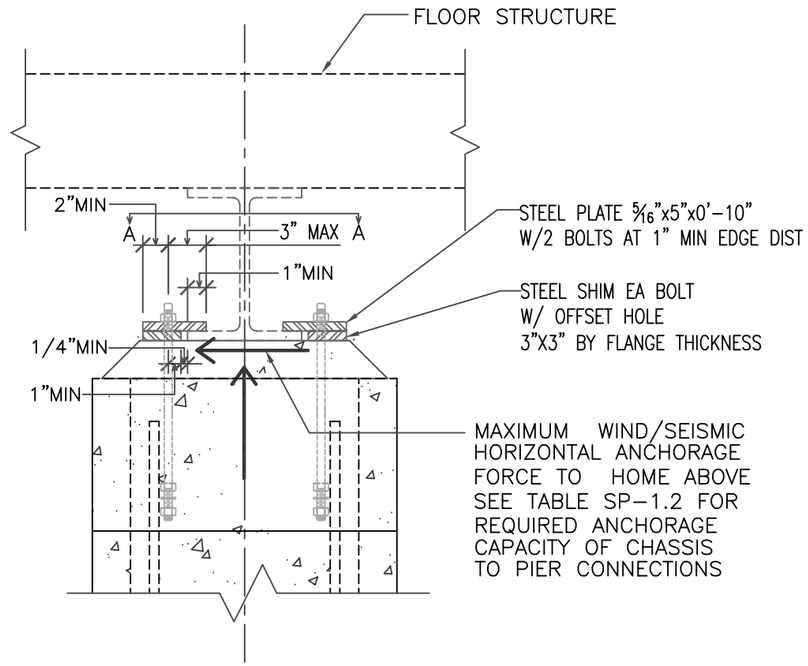

CHASSIS BEAM. DO NOT CUT, DRILL, OR OTHERWISE MODIFY WITHOUT SPECIFIC APPROVAL
FLOOR STRUCTURE
NON–SHRINK PORTLAND CEMENT GROUT, 2" MAX.
SEE FIGURE SP–1.2 FOR ANCHORAGE
ANCHOR BOLT OR APPROVED ADHESIVE ANCHOR
2"
8" MIN
16" X 16" NOMINAL CONCRETE MASONRY PIER, FULLY GROUTED
PIER HEIGHT ABOVE LOWEST ADJACENT GRADE SEE TABLE SP–1.1
5/8" MIN CLR
TWO NO. 4 REBARS IN DIAGONALLY OPPOSITE CORNERS
MIN. DEPTH PER TABLE SP–1.1 DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
3" CLEAR BOTTOM AND SIDES
CAST–IN–PLACE CONCRETE FOOTING
SQ FTG MINIMUM LENGTH AND WIDTH PER TABLE SP–1.1

FIGURE SP–1.1 PRESCRIPTIVE PIER REQUIREMENTS FOR SEISMIC DESIGN CATEGORIES D_0, D_1, D_2, AND E

THE HEIGHT OF PIERS ABOVE LOWEST ADJACENT GRADE SHALL NOT VARY BY MORE THAN TWO FT, AND NO PIER SHALL EXTEND TO MORE THAN 5 FT. ABOVE ADJACENT GRADE.

THE LENGTH AND WIDTH OF THE PIER FOOTING SHALL NOT BE LESS THAN REQUIRED BY TABLE SP–1.1 (SHEET SP–1/2.1), BASED ON THE APPLICABLE ALLOWABLE STRESS DESIGN SOIL BEARING STRENGTH.


FLOOR STRUCTURE
2"MIN
A
3" MAX A
1"MIN
STEEL PLATE 5/16"x5"x0'–10" W/2 BOLTS AT 1" MIN EDGE DIST
STEEL SHIM EA BOLT W/ OFFSET HOLE 3"X3" BY FLANGE THICKNESS
1/4"MIN
1"MIN
MAXIMUM WIND/SEISMIC HORIZONTAL ANCHORAGE FORCE TO HOME ABOVE SEE TABLE SP–1.2 FOR REQUIRED ANCHORAGE CAPACITY OF CHASSIS TO PIER CONNECTIONS

FOR BALANCE OF INFORMATION SEE FIGURE SP–1.1

FIGURE SP–1.2 ANCHORAGE BETWEEN PIER AND CHASSIS BEAM

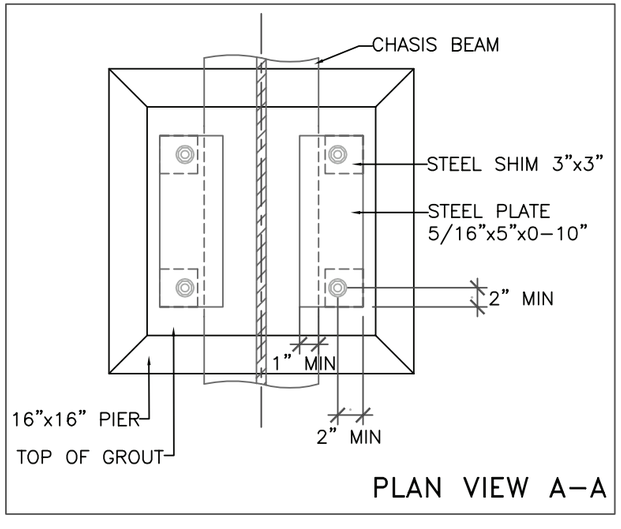


Table SP-1.2 of Pier to Chassis Seismic/Wind Anchorage Forces1

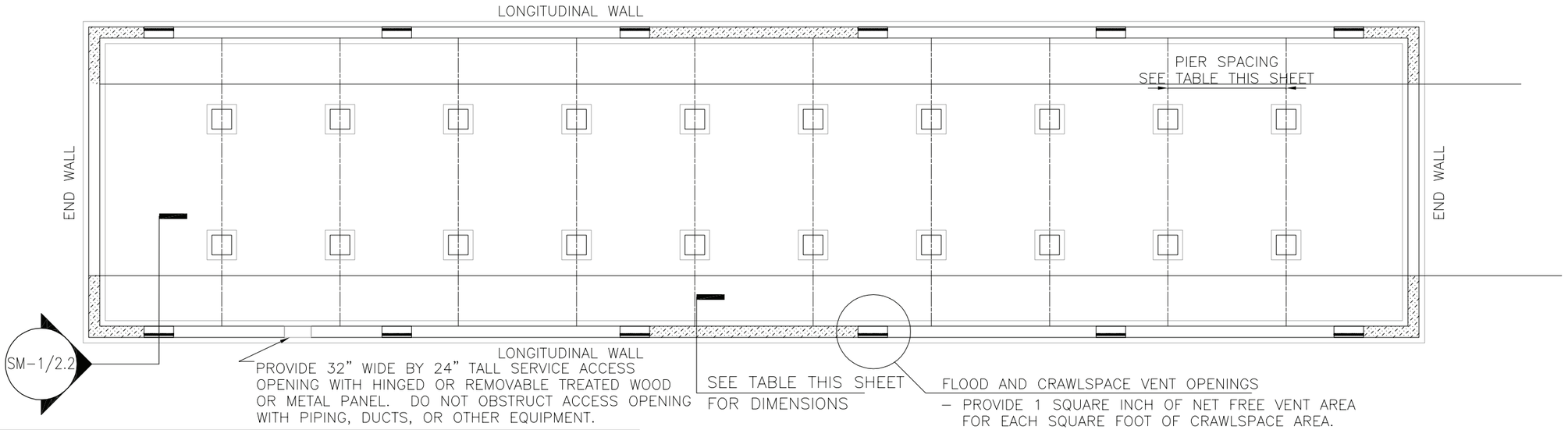
Width	Pier Height (ft)	Maximum Pier Spacing (ft)	Horizontal Seismic/Wind Force Each Pier (lb)	Net Seismic/Wind Uplift Force Each Pier (lb)[2]
single	3	4	320	720
		7	560	1250
		10	800	1790
double	3	4	290	860
		7	440	1510
		10	600	2150
single	5	4	350	720
		7	620	1250
		10	880	1790
double	5	4	340	860
		7	490	1510
		10	650	2150

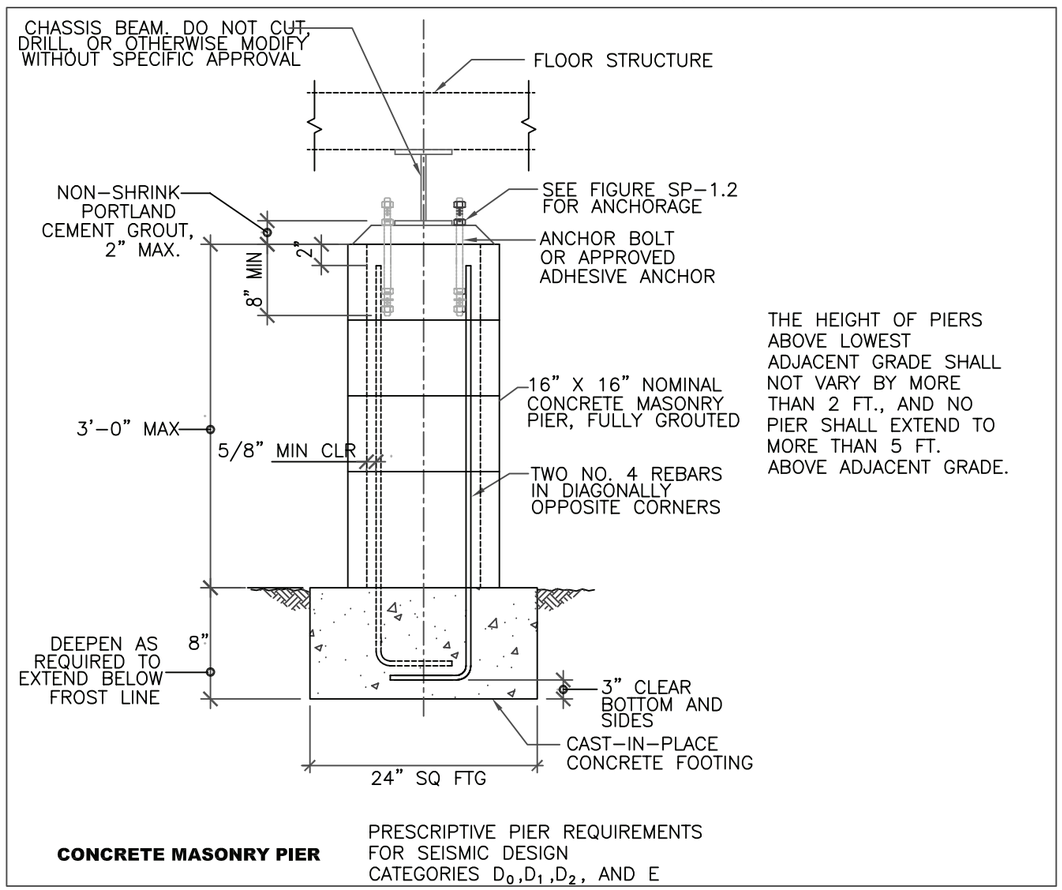
Notes
1. Listed loads are in accordance with ASCE/SEI 7 Section 2.4 Allowable Stress Design (ASD)
2. Based on 14 ft section width. Multiply by 1.15 for 16 ft section width

CONCRETE MASONRY PIER DETAILS

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1


LONGITUDINAL WALL
PIER SPACING
SEE TABLE THIS SHEET
END WALL
END WALL
SM-1/2.2
LONGITUDINAL WALL
PROVIDE 32" WIDE BY 24" TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS, OR OTHER EQUIPMENT.
SEE TABLE THIS SHEET
FOR DIMENSIONS
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.


CHASSIS BEAM. DO NOT CUT DRILL, OR OTHERWISE MODIFY WITHOUT SPECIFIC APPROVAL
FLOOR STRUCTURE
NON–SHRINK PORTLAND CEMENT GROUT, 2" MAX.
SEE FIGURE SP–1.2 FOR ANCHORAGE
ANCHOR BOLT OR APPROVED ADHESIVE ANCHOR
8" MIN
2"
16" X 16" NOMINAL CONCRETE MASONRY PIER, FULLY GROUTED
3'–0" MAX
5/8" MIN CLR
TWO NO. 4 REBARS IN DIAGONALLY OPPOSITE CORNERS
DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
8"
3" CLEAR BOTTOM AND SIDES
CAST–IN–PLACE CONCRETE FOOTING
24" SQ FTG

THE HEIGHT OF PIERS ABOVE LOWEST ADJACENT GRADE SHALL NOT VARY BY MORE THAN 2 FT., AND NO PIER SHALL EXTEND TO MORE THAN 5 FT. ABOVE ADJACENT GRADE.

CONCRETE MASONRY PIER

PRESCRIPTIVE PIER REQUIREMENTS FOR SEISMIC DESIGN CATEGORIES D_0, D_1, D_2, AND E

Maximum Pier Spacing Table - Single Unit

Allowable Soil Bearing Pressure (lb/ft^2)									
	1,000 Less Than 1,500			1,500 To Less Than 2,000			Greater Than 2,000		
Wind Speed	Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)			Ground Snow Load (lb/ft^2)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
90	5'-3"	4'-9"	4'-2"	7'-10"	7'-2"	6'-6"	8'-0"	8'-0"	8'-0"

NOTES

1. THIS DESIGN IS SUITABLE FOR 3-SECOND GUST DESIGN AND SPEEDS UP TO 90 MILES PER HOUR.
2. FOR DOUBLE UNITS, CONSTRUCT FOUNDATION WALL UNDER MARRIAGE LINE.

SINGLE UNIT CONCRETE MASONRY WALL FOUNDATION PLAN

NOT TO SCALE

SEE PRE–ENGINEERED FOUNDATION GENERAL NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEET GN–1.1

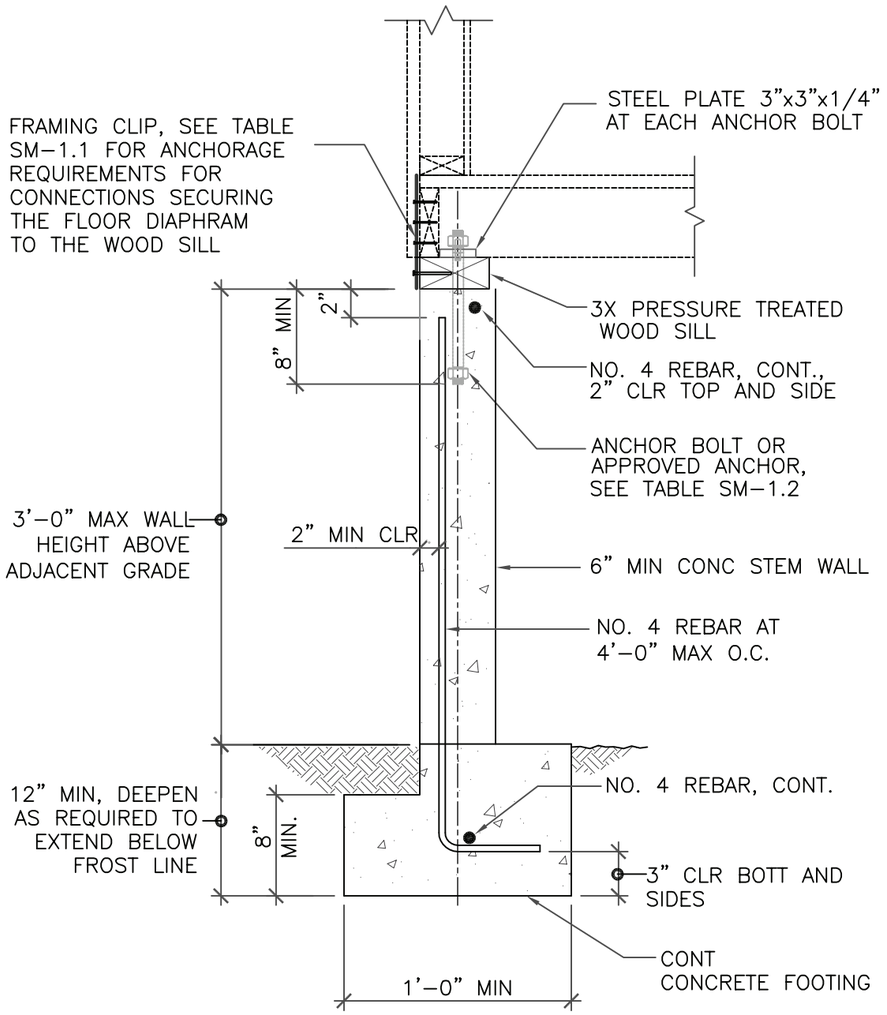

FRAMING CLIP, SEE TABLE SM–1.1 FOR ANCHORAGE REQUIREMENTS FOR CONNECTIONS SECURING THE FLOOR DIAPHRAM TO THE WOOD SILL
STEEL PLATE 3"x3"x1/4" AT EACH ANCHOR BOLT
8" MIN
2"
3X PRESSURE TREATED WOOD SILL
NO. 4 REBAR, CONT., 2" CLR TOP AND SIDE
ANCHOR BOLT OR APPROVED ANCHOR, SEE TABLE SM–1.2
3'–0" MAX WALL HEIGHT ABOVE ADJACENT GRADE
2" MIN CLR
6" MIN CONC STEM WALL
NO. 4 REBAR AT 4'–0" MAX O.C.
12" MIN, DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
8" MIN.
NO. 4 REBAR, CONT.
3" CLR BOTT AND SIDES
CONT CONCRETE FOOTING
1'–0" MIN

FIGURE SM–1.1 PRESCRIPTIVE REQUIREMENTS FOR CONCRETE FOUNDATION WALL IN SEISMIC DESIGN CATEGORIES D_0 , D_1 , D_2 , AND E

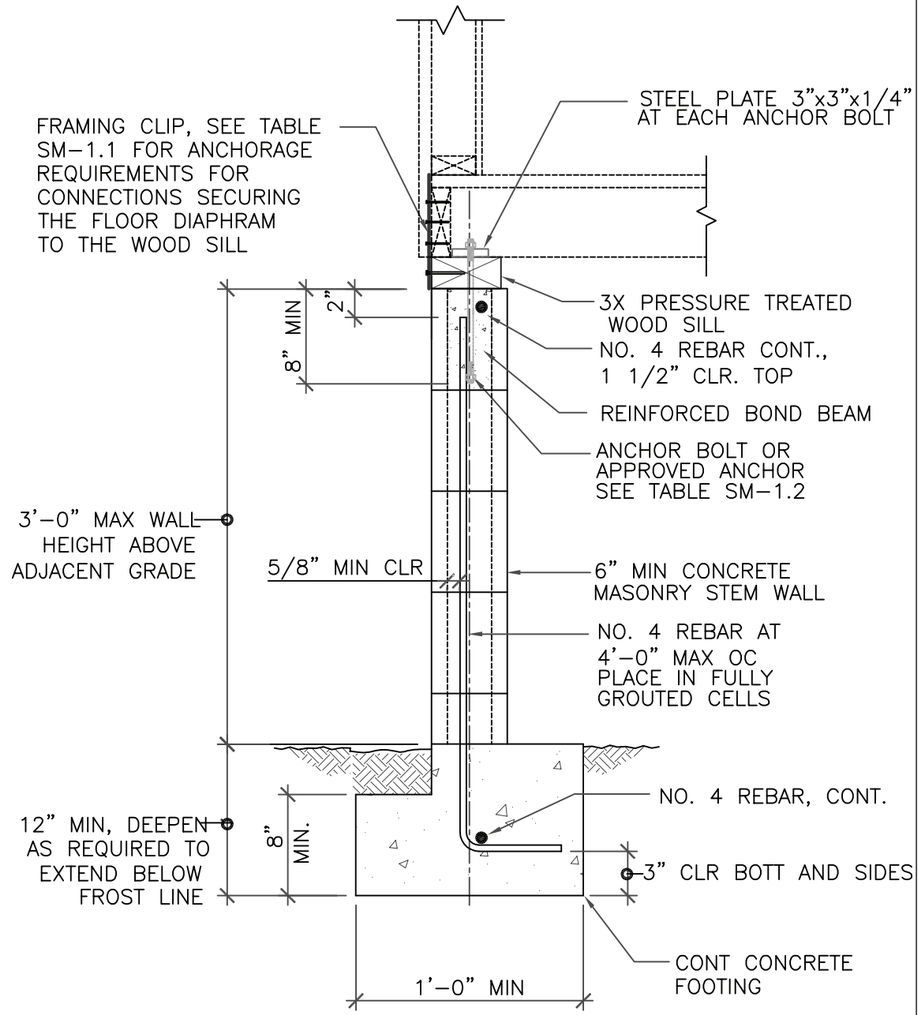

FRAMING CLIP, SEE TABLE SM–1.1 FOR ANCHORAGE REQUIREMENTS FOR CONNECTIONS SECURING THE FLOOR DIAPHRAM TO THE WOOD SILL
STEEL PLATE 3"x3"x1/4" AT EACH ANCHOR BOLT
8" MIN
2"
3X PRESSURE TREATED WOOD SILL
NO. 4 REBAR CONT., 1 1/2" CLR. TOP
REINFORCED BOND BEAM
ANCHOR BOLT OR APPROVED ANCHOR SEE TABLE SM–1.2
3'–0" MAX WALL HEIGHT ABOVE ADJACENT GRADE
5/8" MIN CLR
6" MIN CONCRETE MASONRY STEM WALL
NO. 4 REBAR AT 4'–0" MAX OC PLACE IN FULLY GROUTED CELLS
12" MIN, DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
8" MIN.
NO. 4 REBAR, CONT.
3" CLR BOTT AND SIDES
CONT CONCRETE FOOTING
1'–0" MIN

FIGURE SM–1.2 PRESCRIPTIVE REQUIREMENTS FOR CONCRETE MASONRY FOUNDATION WALL IN SEISMIC DESIGN CATEGORIES D_0 , D_1 , D_2 , AND E

Table SM-1.1 Required Anchorage Capacity Between Foundation Wall and Floor Diaphragm.

Home Width	Wall Location	Horizontal Seismic/Wind Force Per Foot Wall (Shear) (lb/ft)[1]	Net Seismic/Wind Uplift Force Per Foot Wall Length (lb/ft)[1,]
single	end	510	50
	side	70	120
double	end	260	50
	side	140	150

[1] Based on anchorage over entire home perimeter. Forces shall be increase proportionally if anchorage length on any side is decreased.

WHERE ANCHORAGE REQUIREMENTS FROM THE HOME MANUFACTURER ARE NOT AVAILABLE, REQUIRED ANCHORAGE SHALL BE PERMITTED TO USE THE ANCHOR BOLT AND FRAMING PLATES IN ACCORDANCE WITH TABLE SM–1.2.

EACH ANCHOR BOLT SHALL BE PROVIDED WITH A STEEL PLATE WASHER NOT LESS THAN ¼"X3"X3", WITH A HOLE DIAMETER OF 11/16" AND INSTALLED WITH A STANDARD CUT WASHER. SEE FIGURE SM–1.1 AND SM–1.2 FOR PLACEMENT.

Table SM-1.2 Manufactured Home Minimum Perimeter to Foundation Wall Seismic/Wind Anchorage

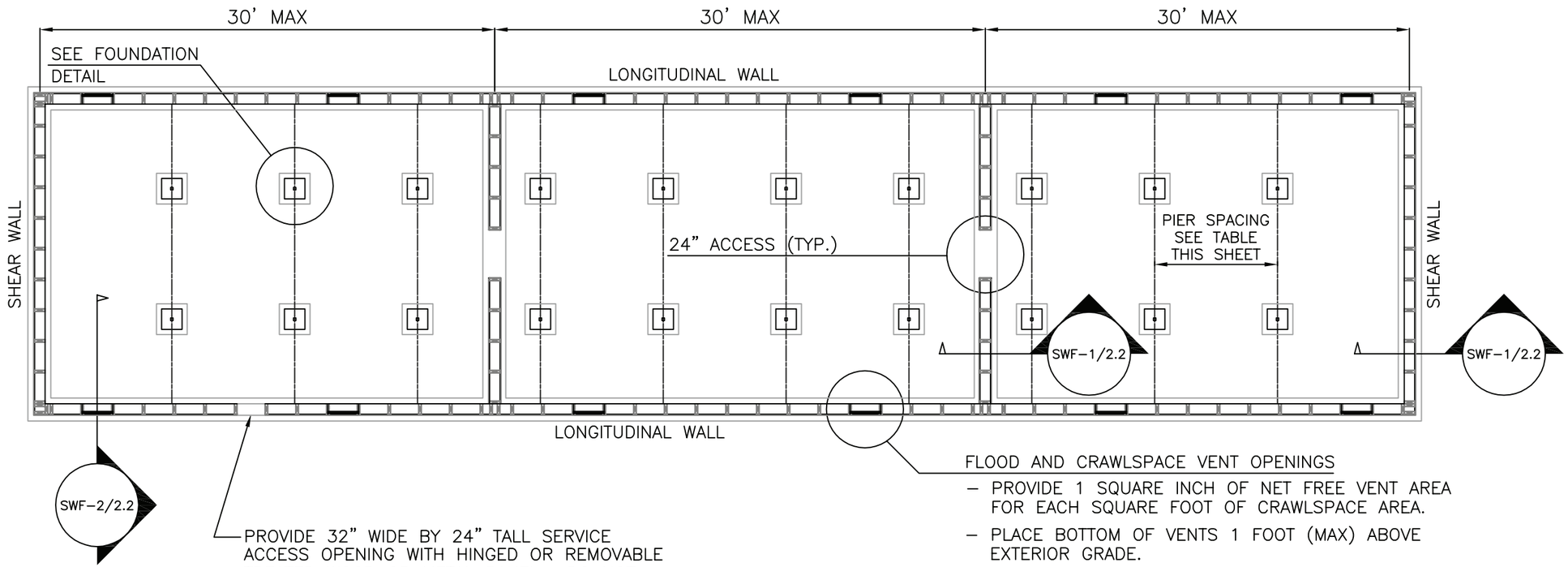
Home Width	Wall Location	Maximum Spacing for 1/2-in Anchor Bolt Anchoring Sill to Foundation Wall (in)	Maximum Spacing for Framing Plate with Shear and Uplift Capacity (in)[1]
single	end	16	12
	side	48	42
double	end	32	18
	side	32	18

[1]Not less than 18 ga. Galvanized plate, fastened to sill and home with not less than six 8d common short nails each.

FOOTING SHALL BE UNIFORM IN THICKNESS ALONG IT'S LENGTH. WHERE REQUIRED FOR SLOPED LOTS FOOTINGS SHALL BE STEPPED WITH MAXIMUM ELEVATION CHANGE OF 18" AND MINIMUM STEP SPACING OF 36".

CONCRETE MASONRY WALL FOUNDATION DETAIL

NOT TO SCALE


30’ MAX
30’ MAX
30’ MAX
SEE FOUNDATION DETAIL
LONGITUDINAL WALL
SHEAR WALL
24” ACCESS (TYP.)
PIER SPACING SEE TABLE THIS SHEET
SHEAR WALL
SWF–1/2.2
SWF–1/2.2
LONGITUDINAL WALL
SWF–2/2.2
PROVIDE 32” WIDE BY 24” TALL SERVICE ACCESS OPENING WITH HINGED OR REMOVABLE TREATED WOOD OR METAL PANEL. DO NOT OBSTRUCT ACCESS OPENING WITH PIPING, DUCTS, OR OTHER EQUIPMENT.
FLOOD AND CRAWLSPACE VENT OPENINGS
– PROVIDE 1 SQUARE INCH OF NET FREE VENT AREA FOR EACH SQUARE FOOT OF CRAWLSPACE AREA.
– PLACE BOTTOM OF VENTS 1 FOOT (MAX) ABOVE EXTERIOR GRADE.
– ALL SCREENS AND LOUVERS MUST AUTOMATICALLY OPEN TO ALLOW UNOBSTRUCTED FLOW OF FLOODWATERS.

Pier Spacing Table - Single Unit

Allowable Soil Bearing Pressure (lb/ft²)									
	1,000 To Less Than 1,500			1,500 To Less Than 2,000			Greater Than 2,000		
Wind Speed	Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)			Ground Snow Load (lb/ft²)		
	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40	Less Than 20	20 To Less Than 30	30 To 40
90	5’-3”	4’-9”	4’-2”	7’-10”	7’-2”	6’-6”	8’-0”	8’-0”	8’-0”

NOTES

1. THIS DESIGN IS SUITABLE FOR 3-SECOND GUST DESIGN AND SPEEDS UP TO 90 MILES PER HOUR.
2. FOR DOUBLE UNITS, CONSTRUCT FOUNDATION WALL UNDER MARRIAGE LINE.

SINGLE UNIT WOOD FRAMED FOUNDATION PLAN

NOT TO SCALE - INTERIOR SHEAR WALL LOCATION FOR 90 MPH DESIGN WIND SPEED

SEE PRE–ENGINEERED GENERAL FOUNDATION NOTES FOR ADDITIONAL INFORMATION, DESIGN CRITERIA AND LIMITATIONS. SHEETS GN–1, WF–3 AND WF–4.

FOOTING SHALL BE UNIFORM IN THICKNESS.
WHERE REQUIRED FOR SLOPED LOTS FOOTINGS SHALL BE STEPPED WITH MAXIMUM ELEVATION CHANGE OF 18" AND MINIMUM STEP SPACING OF 36".

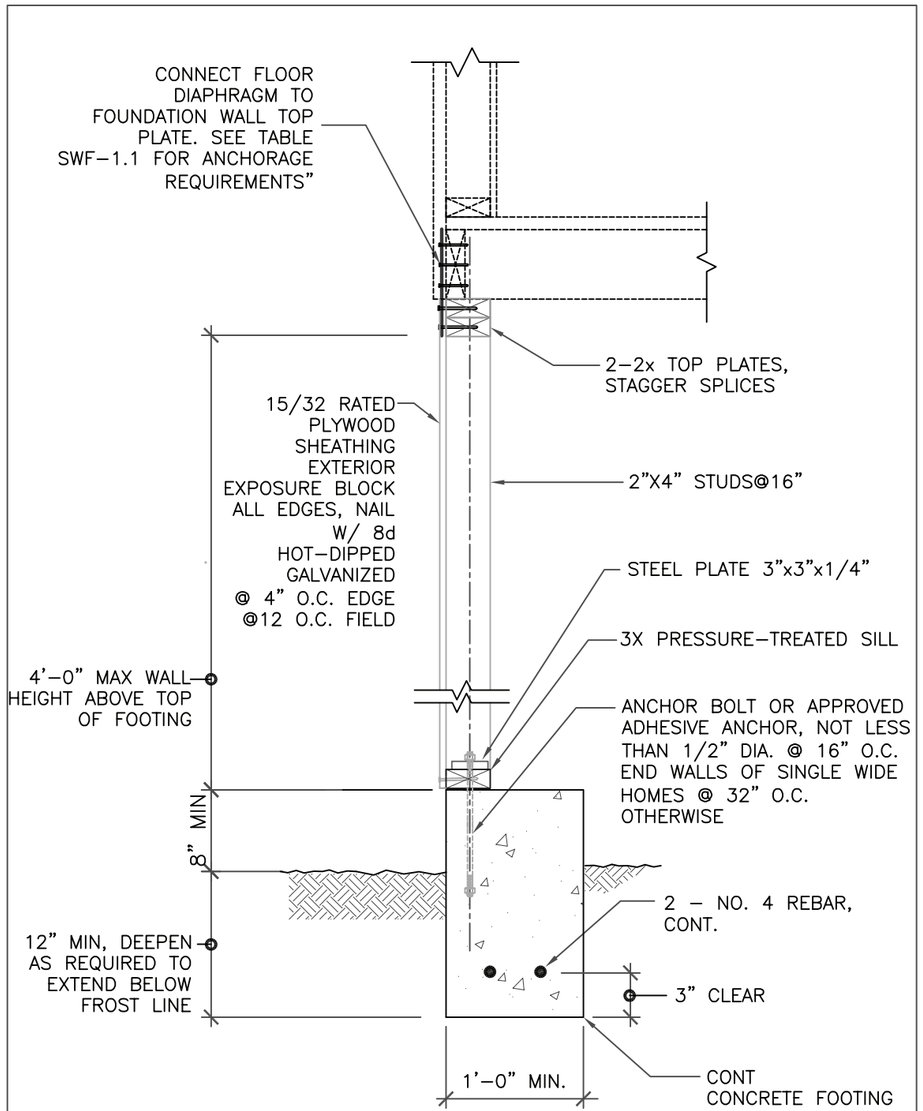
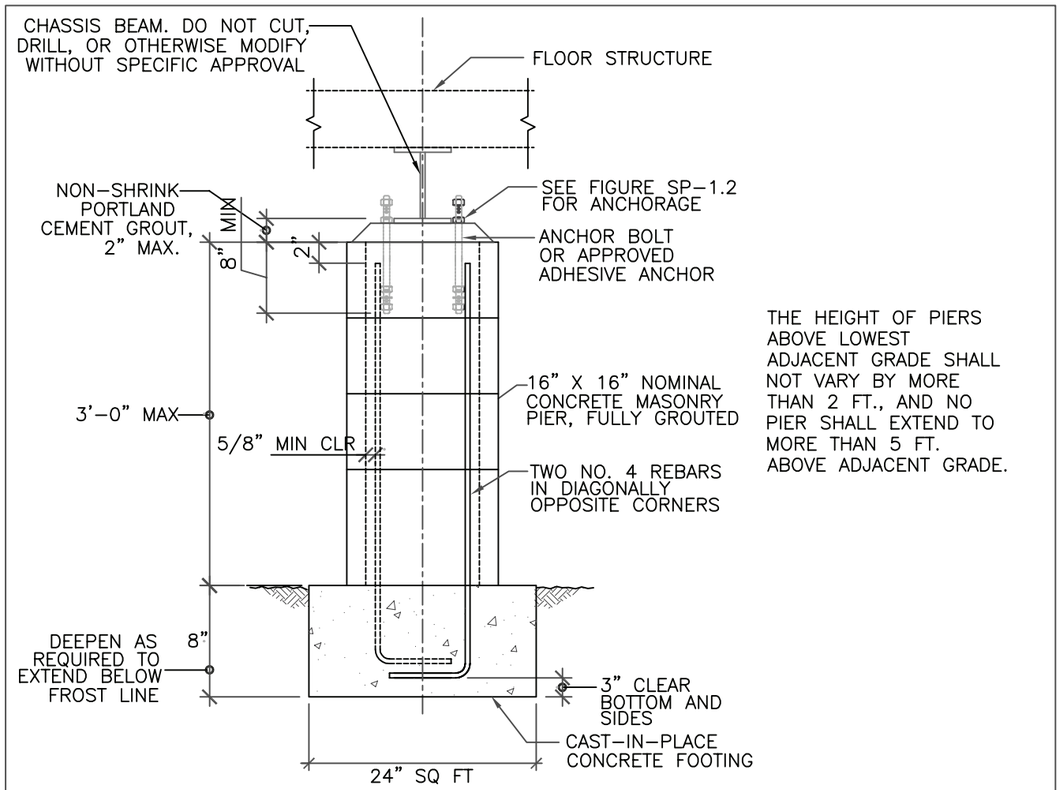

CONNECT FLOOR DIAPHRAGM TO FOUNDATION WALL TOP PLATE. SEE TABLE SWF–1.1 FOR ANCHORAGE REQUIREMENTS"
2–2x TOP PLATES, STAGGER SPLICES
15/32 RATED PLYWOOD SHEATHING EXTERIOR EXPOSURE BLOCK ALL EDGES, NAIL W/ 8d HOT–DIPPED GALVANIZED @ 4" O.C. EDGE @12 O.C. FIELD
2"X4" STUDS@16"
STEEL PLATE 3"x3"x1/4"
3X PRESSURE–TREATED SILL
4'–0" MAX WALL HEIGHT ABOVE TOP OF FOOTING
ANCHOR BOLT OR APPROVED ADHESIVE ANCHOR, NOT LESS THAN 1/2" DIA. @ 16" O.C. END WALLS OF SINGLE WIDE HOMES @ 32" O.C. OTHERWISE
8" MIN
2 – NO. 4 REBAR, CONT.
12" MIN, DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
3" CLEAR
1'–0" MIN.
CONT CONCRETE FOOTING

FIGURE SWF–1.1 PRESCRIPTIVE REQUIREMENTS FOR WOOD CRIPPLE WALL IN SEISMIC DESIGN CATEGORIES D_0 , D_1 , D_2 , AND E

Table SWF-1.1 Manufactured Home Perimeter to Foundation or Cripple Wall Seismic/Wind Anchorage Forces

Home Width	Wall Location	Horizontal Seismic/Wind Force Per Foot Wall (Shear) (lb/ft)[1]	Net Seismic/Wind Uplift Force Per Foot Wall Length (lb/ft)[1,]
single	end	510	50
	side	70	120
double	end	260	50
	side	140	150

[1]Based on anchorage over entire home perimeter. Forces shall be increase proportionally if anchorage length on any side is decreased.


CHASSIS BEAM. DO NOT CUT, DRILL, OR OTHERWISE MODIFY WITHOUT SPECIFIC APPROVAL
FLOOR STRUCTURE
SEE FIGURE SP–1.2 FOR ANCHORAGE
NON–SHRINK PORTLAND CEMENT GROUT, 2" MAX.
8" MIN
2"
ANCHOR BOLT OR APPROVED ADHESIVE ANCHOR
THE HEIGHT OF PIERS ABOVE LOWEST ADJACENT GRADE SHALL NOT VARY BY MORE THAN 2 FT., AND NO PIER SHALL EXTEND TO MORE THAN 5 FT. ABOVE ADJACENT GRADE.
16" X 16" NOMINAL CONCRETE MASONRY PIER, FULLY GROUTED
3'–0" MAX
5/8" MIN CLR
TWO NO. 4 REBARS IN DIAGONALLY OPPOSITE CORNERS
DEEPEN AS REQUIRED TO EXTEND BELOW FROST LINE
8"
3" CLEAR BOTTOM AND SIDES
CAST–IN–PLACE CONCRETE FOOTING
24" SQ FT

CONCRETE MASONRY PIER PRESCRIPTIVE PIER REQUIREMENTS FOR SEISMIC DESIGN CATEGORIES D_0 ,D_1 ,D_2 , AND E

WOOD FRAMED FOUNDATION DETAIL

NOT TO SCALE

FEMA

FEMA P-85
Catalog No. 08211-1